SCIENCE 8

MODULE 4

MECHANICAL SYSTEMS

Learning Technologies Branch

Alberta LEARNING

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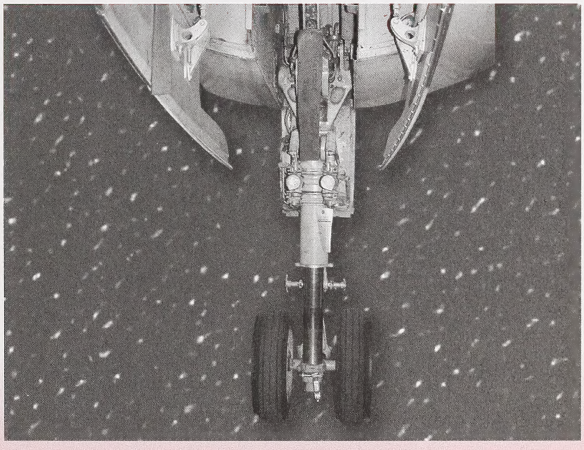
MECHANICAL SYSTEMS 4



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Alberta LEARNING

Science 8
Module 4: Mechanical Systems
Student Module Booklet
Learning Technologies Branch
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The Learning Technologies Branch acknowledges with appreciation the Alberta Distance Learning Centre and Pembina Hills Regional Division No. 7 for their review of this Student Module Booklet.

This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

You may find the following Internet sites useful:

- Alberta Learning, **http://www.learning.gov.ab.ca**
- Learning Technologies Branch, **http://www.learning.gov.ab.ca/ltb**
- Learning Resources Centre, **http://www.lrc.learning.gov.ab.ca**

The use of the Internet is optional. Exploring the electronic information superhighway can be educational and entertaining. However, be aware that these computer networks are not censored. Students may unintentionally or purposely find articles on the Internet that may be offensive or inappropriate. As well, the sources of information are not always cited and the content may not be accurate. Therefore, students may wish to confirm facts with a second source.

WELCOME

MODULE 1 Mix and Flow of Matter

MODULE 2 Cells and Systems

MODULE 3 Light and Optical Systems

MODULE 4 Mechanical Systems

MODULE 5 Freshwater and Saltwater Systems

Contents

Resources

Textbook

To complete the course, you need the textbook *ScienceFocus 8*.

Multimedia

Attached to Module 1 of this course is a CD titled *Science 8 Multimedia*. This CD contains multimedia segments designed to help you better understand particular concepts presented in this course. Ask your teacher or home instructor if you need help using this CD.

Materials and Apparatus

A list of materials and apparatus is given on page 10 of each Student Module Booklet. These items are needed to complete the module. Some of the materials and apparatus may be provided at your local school lab. If you don't have access to a school lab, you will need to get the loan kit. Talk to your teacher for more information.

Before You Begin

Organize your materials and work area before you begin: Student Module Booklet, textbook, notebook, pens, pencils, and so on. Make sure you have a quiet area in which to work, away from distractions.

Because response lines are not provided in the Student Module Booklet, you'll need a looseleaf binder or notebook to respond to questions and complete charts. It's important to keep your lined paper handy as you work through the material and to keep your responses together in a notebook or binder for review purposes later.

Refer to the Planning Ahead page for directions on what you need to do before you start this module.

Good luck!

Icons

This is one of five Student Module Booklets for Science 8. As you progress through this module, you will meet several icons.

Do Ahead

Some preparation must be started well ahead of the activity or investigation. E.g., start the seedlings for the investigation in Lesson 3.

Teacher or Home Instructor

The teacher or home instructor should be contacted for help, approval of some procedure, or checking answers.

Assignment Booklet

Work needs to be done in an Assignment Booklet.

Safety

You must be very careful when you see this symbol.

Textbook

A reference is made to *ScienceFocus 8*, the student textbook for this distance learning course.

Internet

This is a reference to the Internet. **Note:** Any Internet website given is subject to change.

Multimedia

This is a reference to the *Science 8 Multimedia* CD.

Overview

How many tools have you used today? When you cut, stirred, and lifted your food, you used levers. When you opened the window blinds, you used pulleys. When you cut out a picture from a magazine, you used a pair of levers with wedges. If you got around in a wheelchair, you used a wheel and an axle. And that's only a beginning!

You wouldn't have pulleys, levers, wedges, or wheels to make tasks easier in a world without mechanical devices. There would be no cars, refrigerators, furnaces, running water, can openers, bicycles, or airplanes.

Section 1
Mechanical Advantage and Energy

Section 2
Fluid Systems and Complex Machines

Section 3
Machine Technology and Society

To make good use of mechanical devices, insight is needed into how machines operate or perform a certain function.

In this module you will see how some mechanical devices perform functions by controlling motion or by transferring or converting energy. You will discover how components of mechanical devices are linked and compare past and present mechanical devices to see how they have changed. You will also evaluate mechanical devices based on how efficiently they use energy, how effectively they carry out their function, and how they affect your daily life, your community, and the environment.

Assessment

The booklet you are presently reading is the Student Module Booklet. It will show you, step by step, how to advance through Module 4: Mechanical Systems.

This module, Mechanical Systems, has three sections. Within each section your work is grouped into lessons. Within the lessons there are readings, investigations, activities, and questions for you to do. By completing these lessons you will discover scientific concepts and skills, develop a positive attitude toward science, and practise or apply what you have learned.

Suggested answers in the Appendix of this Student Module Booklet will provide you with immediate feedback on the answers to questions in the lesson. Your teacher or home instructor will also provide you with feedback on your progress through the module.

At several points in this module you will be directed to an accompanying Assignment Booklet. Your grading in this module is based on the assignments you submit for assessment. In this module you are expected to complete three section assignments and a Final Module Assignment.

The mark distribution is as follows:

Assignment Booklet 4A	
Section 1 Assignment	49 marks
Section 2 Assignment	39 marks
Assignment Booklet 4B	
Section 3 Assignment	16 marks
Final Module Assignment	38 marks
TOTAL	142 marks

Planning Ahead

Here is a list of materials and apparatus you will need to complete this module.

Section 1

- ❑ a protractor
- ❑ a strong stick or a board
- ❑ a brick or a heavy mass
- ❑ strong string
- ❑ a pair of large scissors
- ❑ thumbtacks
- ❑ a 10-N spring scale
- ❑ a metric tape measure or a metre-stick
- ❑ masking tape
- ❑ two broom handles or similar smooth poles
- ❑ two single pulleys
- ❑ 1-m mason's cord with a loop at each end
- ❑ a toy car or other object for pulling up a ramp
- ❑ books or blocks for ramp support
- ❑ a smooth, flat board
- ❑ about 4 m of rope or strong twine
- ❑ one of the following alternatives
  - a set of two or more toy gears
  - old gears
  - cardboard, scissors, and two thumbtacks

Section 2

- ❑ small balloons
- ❑ a pin or a needle
- ❑ a blunt pencil
- ❑ a pair of scissors
- ❑ paper
- ❑ construction materials for the silly system (See page 328 of the textbook.) (optional)
- ❑ one of the following alternatives
  - an empty thread spool, a 10-cm square piece of cardboard, and glue
  - a light funnel
  - the top curved part of a small pop bottle

Section 3

- ❑ a large sheet of paper
- ❑ a small sheet of paper
- ❑ coloured felt markers
- ❑ tape

In Section 3: Lesson 2, you will need to get two bicycles. See the "Do Ahead" icon on page 68.

If you have access to the Internet, you may want to check out some of the links for this module ahead of time. Go to the following site:

http://www.mcgrawhill.ca/school/booksites/sciencefocus+8/student+resources/toc/index.php

Section 1

Mechanical Advantage and Energy

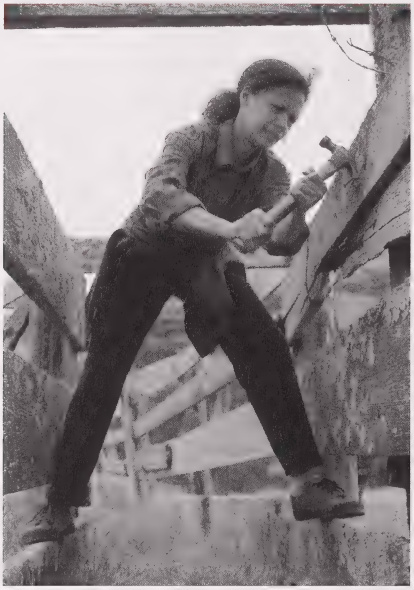
When did you last open a door like the one pictured at the bottom of this page?

Such a door is fairly easy to push open when you place your hand near the latched edge of the door. Sometimes, though, you may end up placing your hand near the hinged edge of the door. You find out that you have to push much harder. On the other hand, you don't have to push as far.

Usually there is a trade-off between how hard you have to push and how far you have to push. How hard you have to push is called effort force. When a mechanical device makes the effort force less, you say the device gives you a mechanical advantage. Determining the mechanical advantage for a device often indicates how well the device performs a function.

In this section you will investigate how well simple machines—levers, inclined planes, wheel and axles, and pulleys—can perform functions. You will also see how simple machines can work together to provide a function.

Lesson 1: Levers and Inclined Planes



The Lever

The lever and the inclined plane were likely the first simple machines used by humans. These machines changed the amount of force needed to move objects.

Consider having to pull out a nail from a board. Would using a hammer (a lever) make the job simpler? Does holding the hammer closer to the head or closer to the handle end make any difference?

Consider the ramp (an inclined plane). If the vertical distance is set, would it be easier to have a short, steep ramp or a longer, gentle-sloping ramp?

If you know the answer to these questions, you are on your way to understanding simple machines.

Read about levers on pages 270 and 271 of the textbook. Study all the diagrams carefully.

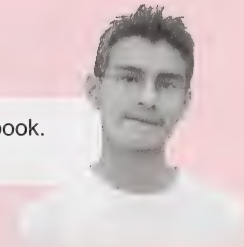
1. Write definitions for the following terms: *lever, fulcrum, effort arm, load arm, load, load force* (F_L), and *effort force* (F_E).

2. Turn to page 284 of the textbook. Answer question 1 from "Topic 1 Review."

3. Answer "Did You Know" on page 271 of the textbook.

Compare your responses with those in the Appendix on page 78.

In this lesson, and in the rest of this course, you will be doing written work. You will sometimes be directed to an Assignment Booklet to do this written work. However, for the numbered questions in Student Module Booklets, you should answer the questions in a notebook set aside for Science 8.



Also, use the notebook to record results while doing science investigations.

The following investigation provides you with some hands-on experience using levers. Practice your terms as you "play."

Investigation 4A Levers In Action

Refer to the "Inquiry Investigation" on pages 272 and 273 of the textbook.

Carry out the steps of "Procedure." Modify the apparatus as necessary. Use the terms from question 1 of this lesson as you perform the investigation.

Use a data table like the following to record your observations. Include a diagram in the "Class" column. Use terms such as less than (<), equal to (=), or greater than (>) to describe the force you had to use to lift the load. A sample entry is given.

Experiencing Levers

Class	Force I Applied Compared to the Weight Lifted	Effort Force (F_E) to Load Force (F_L) Ratio (=, <, >)	Comments
	equal	$F_E = F_L$	My hand and the load moved the same distance.

4. Answer questions 1 to 4 of "Analyze" and "Conclude and Apply."

Check your answers with your teacher or home instructor.

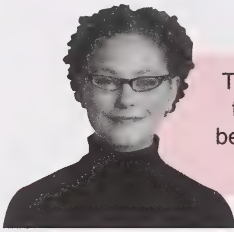
You have seen that when you exert a force on a lever, the lever exerts a force on the load. You discovered that the effort you need to lift the load varied. The force you had to use depended on where the load, fulcrum, and effort force were placed.

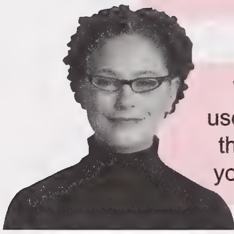
***weight:** the force of gravity exerted on a mass*

***simple machine:** a basic tool or device that transfers energy to do useful work*

***force advantage (FA):** the advantage provided by a machine that makes the required effort force less than the load force*

The force you used was sometimes less than the **weight** of the load. This made it easier to lift the object. Did you notice, however, that your hand moved farther than the load did? In fact, the farther your hand moved, the easier it was to lift the load. When the force you apply (F_E) is less than the weight of the load (F_L), the **simple machine** is providing a force advantage (FA). A **force advantage** makes it easier to move a load.





***speed advantage (SA):** the advantage provided by a machine that makes the load move faster than the effort force*

When the load moves farther than your hand, the simple machine is providing a **speed advantage** (SA). It's harder to move the load, but the load moves farther. When the load moves farther than the effort force in the same amount of time, it's moving faster.

It's sometimes very useful to have the load move fast. Prove this to yourself by sweeping the floor! A broom is a Class 3 lever. Your top hand is the fulcrum, while your lower hand applies the effort force, and the head of the broom is the load. Observe that the head of the broom (F_L) normally moves a much greater distance than your lower hand (F_E) when you sweep—this provides a speed advantage. Try sweeping without moving your lower hand. Cleaning the floor would take a lot longer when your hand and the head of the broom move the same distance.

Play the *Science 8 Multimedia* CD on a computer. This CD is in Module 1 of this course. Once the first screen appears, select the title "Levers." This will show levers in everyday mechanical devices. It will also review how levers can benefit you.

Your experience with levers applies to all types of machines—including simple machines. This module focuses mainly on simple machines that are moved with an effort force applied by a person.

There are six types of simple machines. They are the following:

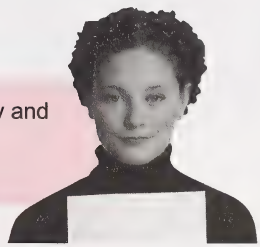
- inclined planes or ramps
- wheel and axles
- screws
- levers
- wedges
- pulleys

The wedge and screw are based on the ramp. You have probably lifted objects by moving them up a ramp. If you wrap the ramp around a cylinder or cone, you have a screw. If you force the inclined plane into or under an object—instead of moving the object—you are using a wedge. When you cut something with an axe or scissors, you are using a wedge.

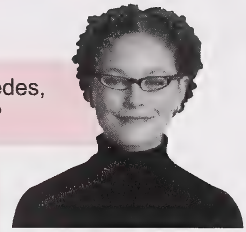
All machines and simple machines follow certain rules. You discovered some of these rules during your investigation of levers. These rules are listed in "Mechanical Device Rules" on page 95 in the Appendix of this module. Read through them.
You may not yet have the background to understand them fully. Don't worry about that. Just keep in mind that these rules are in the Appendix as both a handy reference and a review.

Think about Rules 1, 2, and 4. Do they agree with what you experienced and observed with levers?

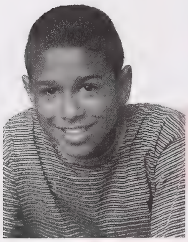
Refer to these rules regularly and apply them to each machine throughout the module.



Levers in Real Life

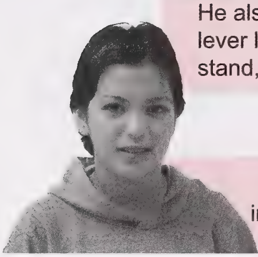


Remember Archimedes, the Greek scientist?



Yes, he came up with Archimedes' principle.

He also made this claim: "Give me a lever long enough and a place to stand, and I will move the Earth."



Archimedes must have been impressed with the power of levers.

Find out about levers in the human body and in space by reading pages 274 and 275 of the textbook.

I find it easy to classify levers by looking at the part in the middle. I think, "1,2,3,F,L,E."

In a Class 1 lever, the **F**ulcrum is in the middle.
In a Class 2 lever, the **L**oad is in the middle.
In a Class 3 lever, the **E**ffort is in the middle.

5. Study the levers in Figures 4.5A, B, and C on page 274 of the textbook. Classify each lever as Class 1, Class 2, or Class 3.

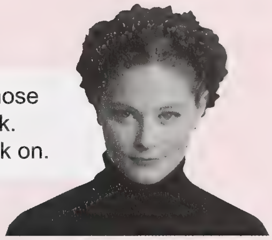
Check your answers with your teacher or home instructor.

Going Further

Learn more about the International Space Station or the Hubble Telescope by visiting the NASA site:

www.nasa.gov

These "Going Further" sections are for those of you who want to do extra in-depth work. There are lots of interesting topics to work on.



Work—From a Scientific Point of View

Can you see the chemistry among these chemistry students?

To make any sense of this question, you have to know that the word *chemistry* is being used in two ways.

One definition of *chemistry* is mutual attraction or rapport. The word *chemistry* can also refer to a subject in school. As a subject, chemistry deals with the characteristics of simple substances and the changes that take place when they combine to form other substances.

It's important to understand the way words are used and to use them properly. In everyday English, work is something you do that takes effort and concentration. It is opposite to play.

In science, the word *work* has a special meaning.

To find the scientific meaning of *work*, turn to page 276 of the textbook and read "What Is Work?" Recall that energy is the capacity to do work. For example, a coiled spring or a rock at the edge of a cliff both have energy.

Note: Recall from Module 1 that 1 N is approximately the weight of a 100 g mass.

When deciding whether or not (scientific) work is done, two conditions must be met:

- A force must be applied on an object.
- The object must move in the direction of the force.

For example, suppose you were walking beside an overfilled grocery cart pushed along—in a straight line—by your dad. You walked along and pushed on the bag of potatoes to keep it from moving and sliding off the cart. You would be doing something useful but it would not be work—at least from a scientific point of view.

6. Decide whether work is being done in each of the following situations.

  a. You hold an apple in your hand.
  b. You move the apple up to your mouth.

From the reading, you've learned that work is a special kind of activity. But the reading gives an additional meaning to work. Work is a quantity—the quantity you get by multiplying force and distance.

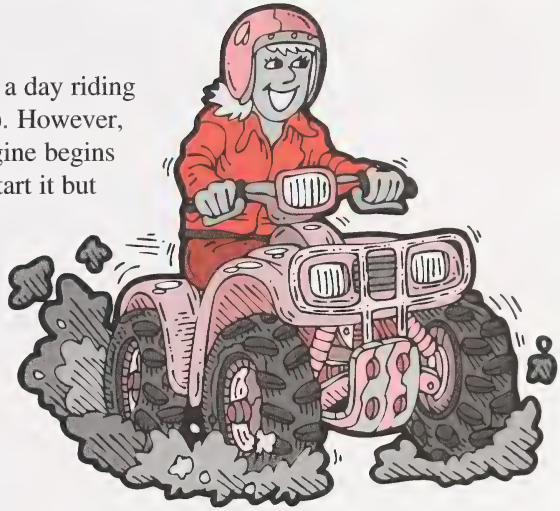
7. Find the quantity of work in each situation. Use the work formula. Show your calculations.

  a. Answer the question on page 276 in the textbook. (This question is below the sample work calculation.) . . . how much work did the lever do on the brick?

  b. You push on a wall with a force of 500 N. How much work did you do?

Compare your responses with those in the Appendix on page 79.

The Inclined Plane



Imagine that you are about to enjoy a day riding the family all-terrain vehicle (ATV). However, soon after starting the ATV, the engine begins to sputter and it dies. You try to restart it but have no luck.

It looks like it will have to be sent into town for repairs. You need to get the ATV into the back of the truck. You can't lift the ATV so you look around for something to serve as a ramp. You find several lengths of thick plywood. The short one is easiest to carry. However, you decide that hauling out the longest one is a good idea. You know that for a given height, the longer the ramp, the smaller the slope. The smaller the slope, the easier it will be to move the load. Now with only one other person, you will likely be able to push the ATV along the ramp and into the truck.

Your decision to use the longest length of plywood available was based on practical experience. Look at Figures 4.7A and 4.7B on page 276 of the textbook. Olivia also used practical experience to lift a box that was too heavy to carry.

Read "The Inclined Plane" on page 276 of the textbook.

8. Using an inclined plane allows you to apply a lower force over a greater distance. Try to predict how using an inclined plane affects the amount of work you do for a particular job. Assume you can ignore friction with the ramp.

Compare your response with the one in the Appendix on page 80.

input work: the work you do on a machine you are using to move a load

output work: the work done by a machine on the load

In the next activity you will explore the relationships between work, force, and distance by moving an object to a particular height. You will use a variety of ramp lengths (and therefore, slopes).

You will also compare the **input work** and the **output work** for the different ramp lengths. This will show whether your prediction about using a ramp was correct.

You will need a protractor for the next investigation.

Turn to "Find Out Activity: Easy Does It" on page 277 of the textbook. Read the introductory paragraph and look at the photo. You will be creating a setup similar to the one in the photo and you will use similar materials. You will require help from your home instructor or a friend or family member.

The activity in the textbook varies the height of the ramp. You will be varying both the length and the slope of the ramp. The longer the ramp, the smaller the slope.

Find Out Activity Relating Work, Force, and Distance

Materials

- a 10-N spring scale
- a protractor
- a toy car or another object for pulling up the ramp (The toy car should weigh between 4 N and 10 N. Can't find a toy car? You may use another object that has wheels or that slides easily. Pick an object that you can easily attach to your spring scale. (You may need string for the connection.)
- a ramp support (for example, several piled books)
- a smooth, flat board, preferably a little more than 1 m long (for example, a bookshelf, a propped-up table, or a length of scrap lumber)
- a metric measuring tape or a metre-stick
- masking tape for marking lengths on the ramp

Note: Spring scales are easily damaged if inappropriately used. Do not bounce things on your scale. Apply force gradually and gently. Prevent the force from going higher than 10 N.

Procedure

Read the entire following procedure before starting this activity.

Step 1: Prepare a data table with a title and column headings as shown.

Force and Work Up a Ramp			
Length of Ramp (m)	Slope of Ramp (°)	Effort Force (N)	Work Done (J)

Although the ramp height will remain the same—it's the height of your stack of books—you will use five different ramp lengths. They are the following:

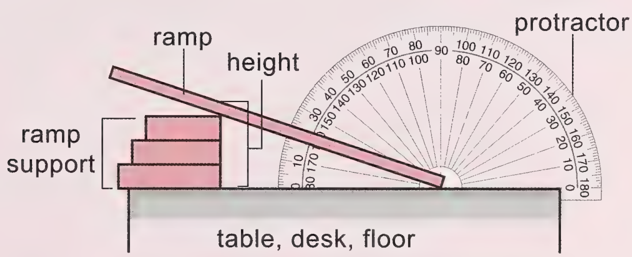
- full length (provide your actual length measurements)
- three-quarter length
- one-half length
- one-quarter length
- no ramp (vertically straight up; think of "ramp length" as equal to the height of the stack of books)

Step 2: Measure and mark your ramp at one-quarter length intervals. Based on a 1-m ramp, mark 25 cm, 50 cm, 75 cm, and 100 cm from the lower end of the ramp. Place the lower edge of the tape at the top of the interval levels. There should still be a little length left over past the 100-cm mark. The extra length supports the upper end of the ramp when you are using it at full length.

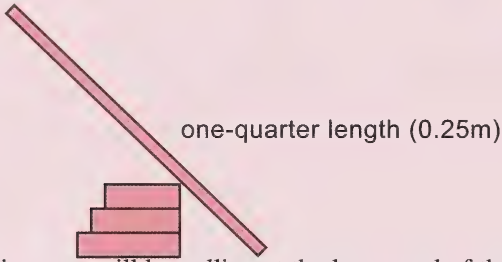
Record the ramp lengths in your data table.

Step 3: To measure your "no ramp" effort force, gently lift your object straight up using the spring scale. Record the weight (not the mass) of the load.

Step 4: Place the ramp on top of your ramp support. Measure and record the distance from the lower end of the ramp to the point where the ramp contacts the books. That's the length of the ramp. Also, use a protractor to measure and record the slope of the ramp.



Step 5: Prop the ramp up on your stack of books. Align the lower edge of the tape at the 0.25 m (one-quarter length) mark with the edge of the stack. Have your helper hold the ramp steady. Measure and record the slope (angle) at the lower end of the ramp.



Step 6: Centre the object you will be pulling at the lower end of the ramp. Slowly and smoothly, pull the load up the ramp. Record an effort force measurement obtained while the load is moving smoothly.

Step 7: Repeat steps 5 and 6 using the one-half, three-quarter, and full-length intervals. Your helper will have to keep the ramp from tipping back over the ramp support.

Step 8: Calculate and record the amount of work you did (input work) for each of the five trials. **Hint:** Multiply the ramp length by the effort force to calculate the amount of work.

What Did You Find Out?

9. Describe how the force needed to pull the toy car (or other object) up the ramp relates to

a. the ramp length
b. the slope angle

10. Describe how the work done in pulling the toy car up the ramp relates to

a. the ramp length
b. the slope angle

11. Using a ramp changes the amount of force and work needed.

   a. Which takes less force—pulling the toy car up the ramp or lifting it directly?

   b. Which takes less work—pulling the toy car up the ramp or lifting it directly? Or didn't you find a difference in the work?

Check your answers with your teacher or home instructor.

Now, check it out. Were the predictions you made about work using a ramp consistent with your findings?

Your calculations may have certainly showed that it took more work to pull your load up the ramp than just lifting it did. Any extra work was done to overcome the force of friction.

Work Input and Work Output

Using any simple machine takes extra work. Yet, the machine can make the work easier to do. Read "Work Input and Work Output" on page 278 of the textbook to expand on this idea.

12. Simple machines do not decrease the amount of work. In fact, you actually end up doing more work with a machine. List three reasons why people still choose to use machines.

13. All machines need energy to operate.

   a. What is the energy source for the simple machines used so far?

   b. Suggest three additional energy sources that could be used to do work with simple or complex machines.

14. You read that climbing five flights of stairs and lifting a compact car 1 m requires about the same amount of work. Explain, in scientific terms, why you could probably climb the flights of stairs but not lift the car.

Compare your responses with those in the Appendix on page 80.

mechanical advantage (MA): *the ratio of the force produced by the machine (load force) to the force applied to the machine (effort force)*

Mechanical Advantage

Could you lift a wheel of a loaded semitrailer truck? It doesn't seem likely! But that's what may have to be done to change a tire "on the road."

If you had a jack you would be able to lift that wheel! That's because a jack gives you a high **mechanical advantage** (*MA*).

Recall that you use machines to do one of the following general tasks:

- indirectly increase the force you can apply to the load
- increase the speed with which you do work
- change the direction of the force

linkage: a device that transfers energy from one object to another within a system (for example, a belt, chain, gear, lever, or rope)

Note: Simple machines may also be used to link one part of a mechanical system to another part. Simple machines and other types of **linkage** transfer energy or motion between system components.

You use a jack to increase the force you can apply to a load.

The next reading will help you describe how much a machine increases the effort force.

Turn to pages 278 to 282 of the textbook and read "What Is Mechanical Advantage?", "Another Way to Calculate Mechanical Advantage," and "Speedy Levers."

The mechanical advantage of a simple machine is a ratio. As you read the textbook, take special note of the methods used for calculating the mechanical advantage.

$$MA = \frac{F_L}{F_E}$$

$$MA = \frac{d_E}{d_L}$$

$$MA = \frac{\text{effort arm}}{\text{load arm}}$$

Note: Symbol Summary

F_E = effort force
F_L = load force
F_A = force advantage
SA = speed advantage
MA = mechanical advantage
$>$ = greater than
$<$ = less than
d_L = distance load moves
d_E = distance effort force moves

15. Record the answers in the blanks for the following statements.

a. The greater the mechanical advantage, the __________ (greater/less) the effort force is compared to the load force.

b. Suppose you move a load with a machine with $MA > 1$. This allows F_E to be __________ (greater than/less than/equal to) F_L, the weight of the load. The machine is providing a __________ (force/speed) advantage.

c. Any machine with $MA < 1$ requires F_E to be __________ (greater than/less than/equal to) F_L, the weight of the load. However, this machine is likely providing a __________ (speed/force) advantage.

d. Any machine with $MA = 1$ requires F_E to be __________ (smaller than/greater than/equal to) F_L.

e. The longer the effort arm, the __________ (greater/less) the effort force needed to move the load.

16. Answer the "Did You Know" question on page 281 of the textbook. Sketch a diagram to help you classify the tweezers.

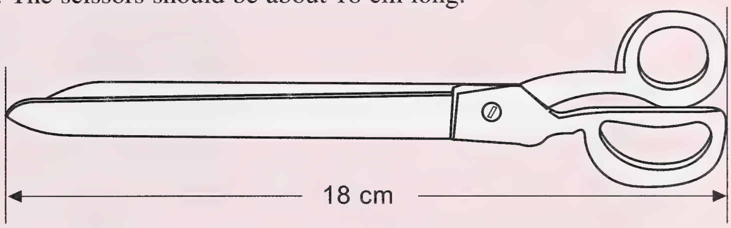
Compare your responses with those in the Appendix on page 81.

Going Further

Do you want to find out about tiny levers that surgeons use to cut and sew? Then read "Cool Tools" on page 281 of the textbook.

Find Out Activity Sharpen Up with Scissors

Turn to page 280 of the textbook. Read the introductory paragraph and record your prediction. Then carry out the steps of "Procedure" by using a pair of large scissors. The scissors should be about 18 cm long.



17. Answer the "What Did You Find Out?" questions from page 280.

Check your answers with your teacher or home instructor.

18. To test your understanding of the concepts in this lesson, answer questions 2 to 5 from "Topic 1 Review" on page 284 of the textbook. You may want to use the "Mechanical Device Rules" in the Appendix.

Compare your responses with those in the Appendix on page 81.

Machines and the Human Body

ergonomics: the science of designing and arranging things to suit the dimensions and other characteristics of the human body

Have you ever sat in a chair that wasn't comfortable? The back may have been too straight. The seat may have been too hard.

Imagine sitting in a wheelchair. It would be even more important that the wheelchair be made for comfort. That's because a person likely sits in a wheelchair for hours at a time.

People who design chairs or wheelchairs must be aware of the possible impact of their products on people. Designers must know about **ergonomics**. Read about ergonomics on page 283 of the textbook.

Industrial designers focus on the machines people use. Dr. Janet Ronsky studies the machine-like characteristics of the human body itself. Read about Dr. Ronsky in "Career Connect" on page 284 of the textbook.

Maybe a career in ergonomics or bioengineering will appeal to you.

Looking Back

In this lesson you investigated two types of simple machines—levers and inclined planes. Levers may be simply used to link parts of a complex machine. But simple machines can do more. Both levers and inclined planes provide a force advantage when they are used to raise heavy objects to new heights. When loads are light, both can be used for speed advantage. A force advantage or a speed advantage can make work easier to do.

In the next lesson you will explore how wheels and axles, gears, and pulleys make work easier to do.

Turn to Assignment Booklet 4A. Complete questions 1 to 5 from Section 1.

Lesson 2: The Wheel and Axle, Gears, and Pulleys

Do you enjoy bicycle riding? Did you know that a bicycle is made up of many simple machines? The brake handles, handle bars, and shifters are levers. The pedal system, gears, and wheels are wheel and axles. Screws connect your bicycle, and wedges work as brakes. All the simple machines operate together to help you move efficiently and in a controlled manner.

The wheel and axle, gears, and pulleys are simple machines that use rotation to allow you to move a load over a large distance—without the natural limitations of levers.

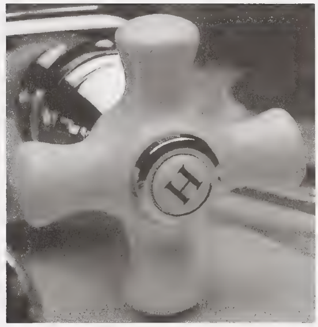
In this lesson you will investigate how these simple machines use rotation to help you do work. You will determine the mechanical advantage of pulley systems and winches and learn how to calculate the speed ratios of such machines.

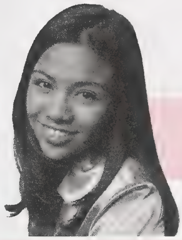
The Wheel and Axle

wheel and axle: a simple machine consisting of two objects attached at their centres so that they rotate together

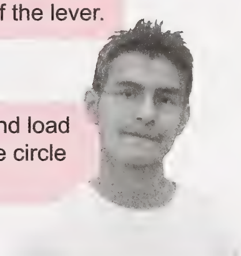
Usually one of the two objects is a wheel. The second object may be a crank, another wheel, or just an axle.

The **wheel and axle** is found in many common devices. Sink and shower taps are examples, as are doorknobs, radio dials, and wheels on a chair or utility cart.





The wheel and axle is really a modification of the lever.



Yes. A clever design allows the effort and load arms of the lever to move in a complete circle around the fulcrum—I mean the axle.

In rotating around an axle, the load and effort force can move over much longer distances.

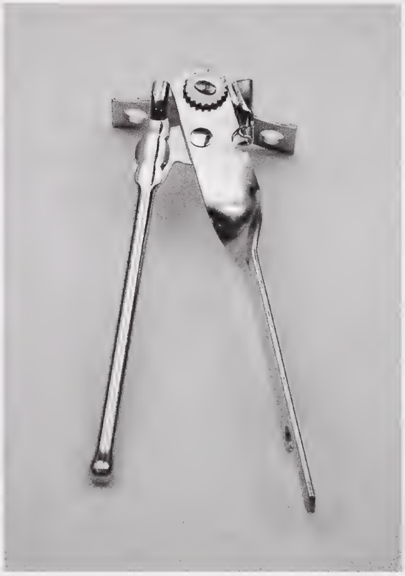
Turn to pages 285 and 286 of the textbook and read "A Lever That Keeps on Lifting" and "The Wheel and Axle." Look carefully at all the diagrams and photos.

1. A winch is an example of a wheel and axle. Explain how a winch resembles a Class 1 lever.

2. Look at the bicycles in Figures 4.14A and 4.14B. Answer the questions below each bicycle.

Compare your responses with those in the Appendix on page 82.

Wheel Advantages



Have you used a manual can opener? This can opener uses a wheel and axle. Like a lever, a wheel and axle can be either a force multiplier or a speed multiplier, but not both at the same time. Which benefit do you think the can opener provides? It's the mechanical advantage ratio that gives you the answer.

Recall that $MA = \frac{\text{load force}}{\text{effort force}}$ for any machine.
To use this formula you would have to try out the machine and measure the load force and the effort force. You'd like to be able to determine the mechanical advantage of a wheel-and-axle device from its design.

In finding the mechanical advantage from the design, you have to keep in mind where the load is attached and where the effort is applied. Here are two cases that show how to find the mechanical advantage of a wheel-and-axle device.

Case 1: The wheel and axle device consists of a "wheel" and a crank.

See the winch in Figure 4.12 on page 285 of the textbook. A winch has a wheel and a crank. (Here the part that corresponds to the wheel is actually a cylinder.)

You can use this formula to find the mechanical advantage:

$$MA = \frac{\text{effort arm length}}{\text{load arm length}}$$

Suppose the length of the handle is 40 cm and the radius of the wheel is 10 cm.

$$\begin{aligned} MA &= \frac{\text{effort arm length}}{\text{load arm length}} \\ &= \frac{40\,\text{cm}}{10\,\text{cm}} \\ &= 4 \end{aligned}$$

The mechanical advantage is 4. The winch is a force multiplier.

In the can opener the gear-like wheel, which runs over the top of the can, pushes the load. The handle forms a crank. The effort is applied to the handle.

The effort arm length is the radius of the handle. The load arm length is the radius of the gear-like wheel.

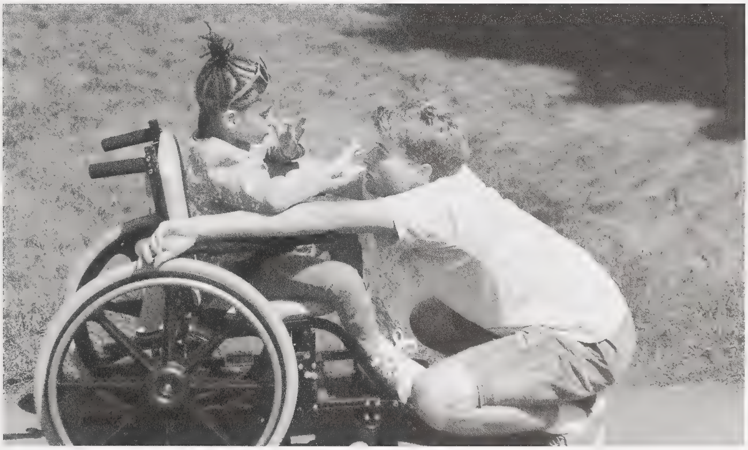
Are you now able to say what benefit a manual can opener gives you?

$$MA = \frac{\text{effort arm length}}{\text{load arm length}}$$

The effort arm is longer that the load arm length. That's because the radius of the handle is more that the effort arm length. That makes the ratio of the effort arm length to load arm length greater than 1. From the formula, it follows that the mechanical advantage is greater than 1. The can opener is a force multiplier.

Case 2: The wheel-and-axle device consists of a large wheel and a small wheel.

On a wheelchair, there are two wheels that contact the ground. Attached to each of these wheels is a smaller chrome rim that is meant for the rider to push or pull by hand.



You can use this formula to find the mechanical advantage of the wheel and axle.

$$MA = \frac{\text{radius of effort wheel}}{\text{radius of load wheel}}$$

Suppose the radius of the effort wheel is 38 cm. (The effort wheel is the smaller chrome rim.) The radius of the load wheel is 40 cm.

$$MA = \frac{\text{radius of effort wheel}}{\text{radius of load wheel}}$$

$$MA = \frac{38\,\text{cm}}{40\,\text{cm}}$$
$$= 0.95$$

The mechanical advantage is 0.95, which is less than 1. The wheelchair gives you a speed advantage.

From these cases you can see that you can find the mechanical advantage of wheel-and-axle devices with these two formulas.

$$MA = \frac{\text{effort arm length}}{\text{load arm length}} \qquad MA = \frac{\text{radius of effort wheel}}{\text{radius of load wheel}}$$

The second formula shows that the mechanical advantage is equal to the ratio of the radii of the wheels. This means the mechanical advantage is also equal to the ratio of wheel circumferences.

$$MA = \frac{\text{circumference of effort wheel}}{\text{circumference of load wheel}}$$

3. Suppose you wanted to design a winch with a mechanical advantage of 8. You planned to use an axle having a radius of 3.5 cm. Determine what length you need for the winch handle. Show your work.

4. Look at the old-fashioned bicycle in Figure 4.14B on page 286 of the textbook. Suppose the length of the crank (the part linking the pedal and the axle) is 25 cm. The speed ratio of the wheel and axle is 7. What would be the radius of the large wheel on the front?

Compare your responses with those in the Appendix on page 83.

Getting the Gears?

Have you been in a car with a standard transmission? Then you know the driver has to move a gearshift to change gears. You may have heard the gears grind when a driver shifts them poorly.

Gears are wheel-like objects with teeth around their circumference. Often, as in transmissions, gears are placed close enough together so that their teeth mesh. Gears may also be kept apart but be connected by a chain, such as on a mountain bike. Gears connected by chains are usually called sprockets. The chain acts as a linkage.

The relative sizes of the gears determines their turn or speed ratios. Gears can be used for speed advantage, force advantage, or simply to change the direction of rotation.

For a description of how gears are used, turn to page 287 of the textbook and read "Gearing Up." Also turn to page 288 for Figures 4.17 and 4.18. Then read "Going the Distance" on page 289.

5. Define *gear, gear train, driving gear (driver), driven gear (follower), sprocket,* and *speed ratio.*

6. Gear teeth must be the same size to mesh. The number of teeth on each gear is directly related to the gear's circumference (and radius). The effort force will be applied to the driver gear, and the load will be applied to the follower gear.

  a. Count and record the number of teeth on the driver gear and the driven gear in Figure 4.15A.

  b. Predict the benefit (gaining a force advantage or gaining a speed advantage) that this gear train will provide.

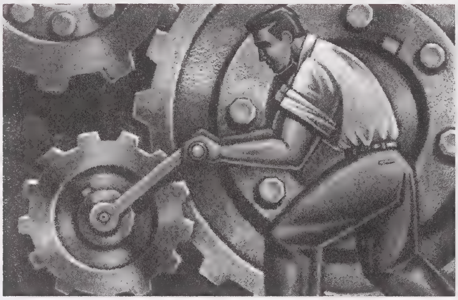
c. Predict the type of advantage(s) this gear train provides if the crank is on the smaller gear.

d. Count the number of teeth on the first and third gears in Figure 4.15B on page 287 of the textbook. If the first gear is the driver, will the load or the effort force go farther in one rotation?

e. What is the purpose of the middle gear in Figure 4.15B?

Compare your responses with those in the Appendix on page 83.

7. Calculate the speed ratios for the gear trains in Figures 4.15A and B. Calculate the ratios using the numbers of teeth.



How do the sizes of the gears in contact affect the number of revolutions made?

Find Out Activity Turnaround Time

Refer to the activity on page 288 of the textbook.

Note: If you are unable to obtain a gear apparatus as suggested in this activity, you may be able to find a set of meshed, different-sized gears in an old toy or clock. Otherwise, you could use the "Gear Templates" from page 96 of the Appendix in this Student Module Booklet. Carefully cut out the gears. Then, using a thumbtack, fasten the two gear wheels to a piece of cardboard with the gear teeth meshed (as illustrated in Figure 4.19A or the photo in the activity).

Carry out the steps of "Procedure."

8. Answer the "What Did You Find Out?" questions.

Check your answers with your teacher or home instructor.

9. The gears on a mountain bike are actually sprockets.

   a. The middle ring of the front set of sprockets of a mountain bike has 42 teeth. It is matched with a 14-tooth rear sprocket. Calculate the speed ratio.

b. If the front sprocket—which provides the effort force—rotates once, how many times will the rear wheel rotate? The rear sprocket is fixed to the rear wheel.

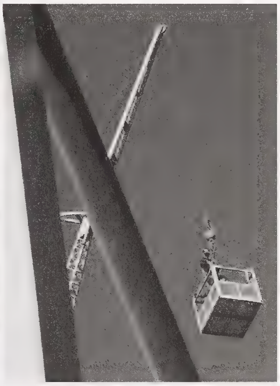
c. What type of benefit(s) will this gear train provide?

Compare your responses with those in the Appendix on page 84.

Going Further

- Get hands-on experience with gears. Try "Inquiry Investigation 4B: Gear Up for Speed" on page 290 of the textbook.

Using Pulleys



pulley: a simple machine made of a wheel with a grooved rim that guides a rope

Imagine constructing and maintaining high-rise buildings without a **pulley**! Have you watched giant cranes raise and lower huge concrete panels? Perhaps you have seen window washers balancing on a high platform. These feats are possible because of the pulley.

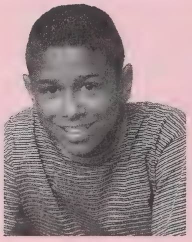
A pulley is a wheel and axle with a groove around the outer edge. A rope fits into this groove and links the load and the effort force. Pulleys can be used alone or in combination.

Play the *Science 8 Multimedia* CD on a computer. This CD is in Module 1 of this course. Once the first screen appears on your computer, select the title "Pulley Power." This will show you the many ways pulleys are used.

Turn to pages 292 and 293 of the textbook and read "Pulleys" and "Supercharging Pulleys."

10. Describe *fixed pulley, movable pulley,* and *compound pulley*. Include a simple, labelled diagram for each type of pulley.

While completing some group work, Max and Lin discuss how the number of support ropes is related to the mechanical advantage of a pulley system.



Max: A single, fixed pulley just changes the direction of your applied force. That would be like on a flag pole. There's only one rope supporting the load, so its *MA* is 1.

Lin: A fixed pulley doesn't reduce the force, but it helps you lift a heavy load by allowing you to pull downward using your body weight. It also lets you apply a force to something you can't reach—like pulling up a flag while standing on the ground.

Max: I like the mechanical advantage of a movable pulley. A single, movable pulley has two ropes supporting its load. It has a mechanical advantage of 2.

Lin: Compound pulleys are even better. The mechanical advantage increases by one for each length of rope that supports the load.

Max: Look at the block and tackle in Figure 4.24. That system has a mechanical advantage of 4.

Lin: Wouldn't you say the mechanical advantage is 5?

Max: Well, there are only four ropes—four rope segments actually—that support the load. The fifth rope segment just makes a change in direction without directly supporting the load. You count only the supporting ropes to figure out the mechanical advantage.

Use "Mechanical Device Rules," if necessary, to predict and confirm the effects of pulleys on effort force, load speed, and work.

Watch pulleys in action by playing the *Science 8 Multimedia* CD. Select the title "Two-Pulley Systems." You'll see how pulleys can work as force multipliers.

11. a. If a compound pulley has a mechanical advantage of 4, how much weight can you lift with an effort force of 50 N?

b. What is the trade-off for the increase in force?

Compare your responses with those in the Appendix on page 84.

The next activity is a great party trick. Amaze your friends and family with your incredible strength. Hopefully, they won't know the secret of mechanical advantage!

Find Out Activity Tug of War

Refer to the activity on page 293 in the textbook.

Note: You will need the help of two of your friends or family members.

12. Answer questions 1 to 3 from "What Did You Find Out?" and "Extension."

Compare your responses with those in the Appendix on page 85.

Going Further

Test your understanding of the relationship between effort force and distance in "Problem-Solving Investigation 4C." The investigation is called "Pick It Up." Refer to the investigation on page 294 of the textbook, where you will design and build a model of a crane that meets specific mechanical design criteria.

Be sure to get approval from your teacher or home instructor before actually carrying out your plans.

A similar challenge is presented in question 5 of the Topic 2 Review on page 295 of the textbook. Give it a try.

13. To test your understanding of the concepts in this lesson, answer questions 1 to 4 of "Topic 2 Review" on page 295 of the textbook.

Compare your responses with those in the Appendix on page 85.

Looking Back

Wheels let a skateboarder reach impressive speeds and heights. Wheels in simple machines help people do work that would be impossible without the wheels.

In this lesson you dealt with simple machines that use rotating parts to make work easier. These simple machines were the wheel and axle, gears, and pulley systems. You found that by looking at both the mechanical advantages and speed ratios of these simple machines, you could see how work was made easier to perform.

Turn to Assignment Booklet 4A. Complete questions 6 to 11 from Section 1.

Lesson 3: Energy, Friction, and Efficiency

NASA/DFRC

On June 12, 1979, the Gossamer Albatross made history by being the first aircraft to cross the English Channel using only human power. The crossing involved a distance of 37 km and a flying time of two hours and 49 minutes.

The pilot provided energy by pedalling, much like you do on a bicycle. To fly using only the small amount of energy the pilot could produce, the Gossamer Albatross had to be light and streamlined in design.

The energy produced by the pilot had to be used very efficiently.

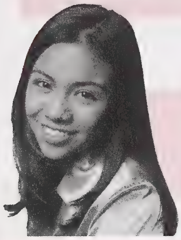
Mechanical devices should be designed for efficiency. When they run efficiently, they are less expensive to use and are more environmentally friendly.

In this lesson you will identify types of energy used in mechanical devices. You will examine the role of friction in mechanical devices. Also, you will look at the efficiency of mechanical devices.

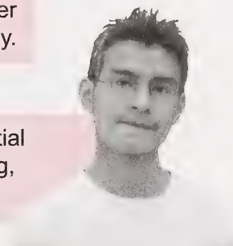
Reviewing Energy

Turn to pages 296 and 297 of the textbook and read “Work and Energy” and “Stored Energy.”

What are some examples of potential energy?



There's chemical potential energy in gasoline. A stretched rubber band has elastic potential energy.



A rock on the edge of a cliff has gravitational potential energy. And a speeding bullet, a compressed spring, and meat and potatoes all have potential energy.

1. Define *kinetic energy* and *potential energy.*

2. Energy is changed—or converted—in many everyday situations. Carefully study Figure 4.26 on page 297 of the textbook. Then answer the questions in the caption.

Compare your responses with those in the Appendix on page 86.

Going Further

To reinforce your understanding of kinetic and potential energy, try “Find Out Activity: A Rubber Roller Coaster” on page 297 of the textbook. Modify the activity to suit the equipment you have on hand.

Transmission, Conversion, and Efficiency

How can you make your bicycle work as efficiently as possible? You know that the amount of work done by a mechanical device is always less than the amount of work done on it. Machines only make doing work easier, faster, or more convenient. How can you keep your energy expenditure down?

Carefully read pages 298 and 299 in the textbook for information about the efficiency of mechanical devices.

3. What is the difference between energy conversion and energy transmission?

4. How does an ideal machine differ from a real machine?

5. How can you boost the efficiency of most machines?

Friction often has a bad reputation. After all, friction keeps machines from running efficiently. Before doing the next question, you may want to play the multimedia segment "Friction: There's the Rub." The segment is on the *Science 8 Multimedia* CD.

6. Is all friction bad? Answer this by providing five examples of useful friction.

7. Read the second "Pause and Reflect" on page 302 of the textbook. Explain why the rust increases the amount of work you have to do.

Compare your responses with those in the Appendix on page 86.

In the following investigation you will explore efficiency and friction in a pulley system. You will also analyze the relationship between effort force and the distance the effort force moves.

Investigation 4D Easy Lifting

Refer to the "Inquiry Investigation" on pages 300 and 301 in the textbook.

Carry out the steps of "Procedure" for Trial A and Trial B. Trial A involves just a single fixed pulley. A single fixed pulley is shown in Figure 4.22 on page 292 of the textbook. Trail B involves a single fixed pulley and a single movable pulley.

Note: Use a load that can be easily attached. Its weight should be close to but not more than 10 N to ensure that you don't damage your spring scale. You may use a handle of a kitchen cabinet as your pulley support.

8. Answer questions 1 to 4 from "Analyze." Just complete the analysis for the trials you did—Trials A and B.

One student named Vashti, who had two double pulleys, completed the steps of the procedure for Trials C to E. Her analysis data table for these trials looked like the following.

Number of Ropes and Mechanical Advantage of Pulley Systems

Trial	Number of Ropes	Mechanical Advantage
C	3	2.8
D	4	3.7
E	5	4.5

9. Answer question 5 of "Conclude and Apply."

Use the following information to answer the next question.

Vashti did some further investigation related to Trial E. She looked at the movement and magnitude of the effort force and load force. She found that when she pulled with a force of 1.8 N on the spring scale through a distance of 15 cm, the load of 8.0 N only moved 3 cm.

10. Answer question 6 from "Extension." Use Vashti's data.

Recall that $W = Fd$

Compare your responses with those in the Appendix on page 87.

You found out something that applies to other simple machines. Using a pulley system increases the amount of work you have to do. However, a pulley system lowers the effort force you need. The lower effort force can make the work easier to perform.

11. To test your understanding of the concepts in this lesson, answer questions 1 to 3 of "Topic 3 Review" from page 302 of the textbook.

Compare your responses with those in the Appendix on page 88.

Looking Back

In this lesson you identified kinetic and potential energy and the role of friction in mechanical devices. You discovered that reducing friction increases the efficiency of machines.

Section Review

To review the concepts covered in this section, turn to page 303 in the textbook and answer questions 1 to 13 (a crossword puzzle) and question 18 from "Wrap-up: Topics 1 to 3.

Check your answers with your teacher or home instructor.

Conclusion

In this section you investigated simple mechanical devices such as the lever, the inclined plane, and devices composed of a rotating wheel and axle. You discovered that using simple or compound mechanical devices can increase an applied force or the speed with which the load moves—but not both at the same time. You calculated mechanical advantage, speed ratios, efficiency, and the work done on and by machines.

You also reviewed energy conversion and the transmission of energy.

Jana is applying her knowledge of a simple machine, the lever, on her exciting, white-water kayaking trip. Simple machines make work or play easier, faster, or more convenient. Understanding the underlying scientific principles helps you select the best tool for the job or the right gear for the terrain.

Turn to Assignment Booklet 4A. Complete questions 12 and 13 from Section 1.

Section 2

Fluid Systems and Complex Machines

Have you travelled through a large road-construction site? Then you have probably seen a huge earthmover in action. Such a mammoth machine is complex. Its operation depends on many subsystems. Some of its subsystems create movement and great force by applying pressure to confined fluids—you may know these as hydraulic systems. In such a complex machine, each component and subsystem is interrelated and interdependent—if one fails, the entire machine would falter or even come to a complete stop.

In this section you will investigate how the relationship among force, pressure, and area is the basis of machines using fluid under pressure—hydraulic and pneumatic technologies. You will compare mechanical, hydraulic, and pneumatic systems to similar systems found in the human body.

Lesson 1: Force, Pressure, and Area

You and your family may have enjoyed riding inflated tractor-tire tubes at a water park. You may have used a water pistol, watched a front-end loader work, flown in an airplane, or played with an air-filled ball.

What is common to all these activities? All of them involve the application of pressure to a fluid.

In this lesson you will review the relationship between pressure, force, and area. You will use the pressure formula. You will see how pressure applied to a confined fluid is transmitted throughout the fluid, and how this idea is used to design machines that make work easier. Comparing mechanical, hydraulic, and pneumatic systems to similar systems found in the human body will also be done.

In the following activity you will review the relationship between area, force, and pressure.

Find Out Activity Pop 'em Quick

Refer to the activity on page 304 in the textbook.

Carry out the steps of "Procedure." Use a dull pencil for step 3.

1. Answer questions 1 to 3 from "What Did You Find Out?"

Compare your responses with those in the Appendix on page 88.

Modifying Pressure

The pressure equation ($p = \frac{F}{A}$) indicates that if a constant force is spread over a larger area, pressure will be reduced. Safety equipment is designed to spread a force over a large area to decrease pressure.

Read pages 304 and 305 in the textbook to reinforce these concepts.

2. Define *pressure*, *pascal*, and *kilopascal*.

3. Do the top "Math Connect" on page 305.

Compare your responses with those in the Appendix on page 89.

You may enjoy applying your knowledge of spreading a force over a large area by designing and building an egg crate. The you'll want to do the next Going Further.

Going Further

Turn to "Problem-Solving Investigation 4E: Egg Drop" on page 306 of the textbook.

Carry out the investigation on your own or with some friends or family members.

Think about the "Evaluate" questions. Use these questions to explain your design to your friends.

DID YOU KNOW?

Read "Did You Know?" on page 306 of the textbook.

The bubble wrap acts as a crush zone around each egg by distancing and absorbing the energy of the impact. In addition to the eggs being individually wrapped, the containers used for these supply drops have a crushable bottom—they usually use corrugated cardboard as the energy-absorbing medium.

Hydraulic Systems

The cargo lift uses a hydraulic system. In Module 1 you were introduced to hydraulic systems. The hydraulic system transfers a force to the lifting mechanism through oil under pressure, a cylinder, and a piston. The cargo lift allows very heavy loads to be lifted to the main floor level of the building from ground level. Once at the main floor level, the loads can be carried by a forklift within the building.

Read about the lifting ability of hydraulic systems in "Pascal's Law" and "Pascal's Law and Mechanical Advantage" on pages 307 to 309 of the textbook.

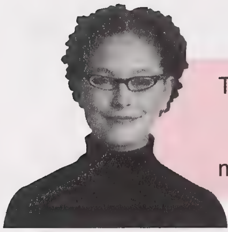
Note: The standard unit of pressure is the pascal (Pa). A pressure of 1 Pa is a force of 1 N applied evenly over an area of 1 m^2.

4. Define *Pascal's law*, *hydraulic lift*, and *closed system.*

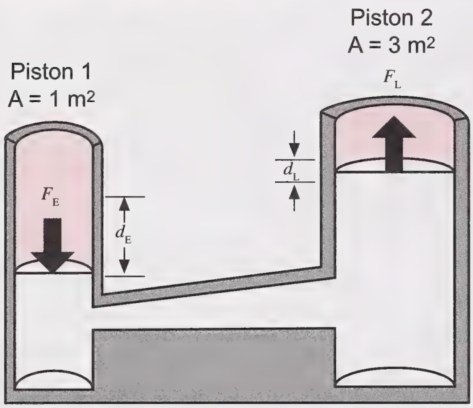
5. What system of your body is a closed hydraulic system?

Compare your responses with those in the Appendix on page 90.

It follows from Pascal's law that the pressure at each piston of a hydraulic lift will be the same. With pressure at each piston the same, only the area of the piston can make a difference in the effort force and applied force at the pistons. The mechanical advantage of a hydraulic lift is based on the ratio of the areas of the pistons.



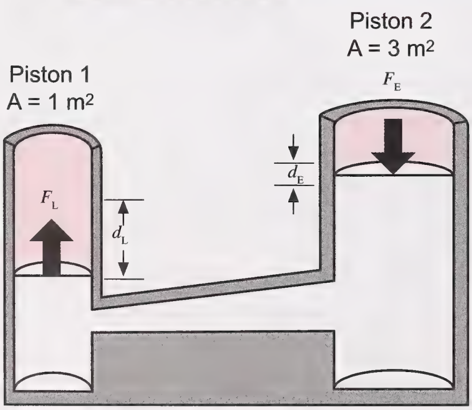
Think of a hydraulic system where Piston 2—the piston with the load—is three times the area of Piston 1—the one you would push. Then the load force that the machine generates will be 3X your effort force. *MA* = 3.



d_E = distance moved by effort force
d_L = distance moved by load force
F_L = load force
F_E = effort force

But you lose in speed advantage. Piston 2, where the load is, will move only $\frac{1}{3}$ as far as Piston 1.

Think about what happens when the load and effort are reversed—if the effort force is applied to Piston 2. What is the mechanical advantage?



Piston 1 is $\frac{1}{3}$ the area of Piston 2 so I think this will happen:

- The generated load force will be only $\frac{1}{3}$ the effort force. That means that the mechanical advantage is only $\frac{1}{3}$.
- Piston 1 and the load will move 3X farther than Piston 2. The speed advantage will be 3.

Right. The mechanical advantage of a hydraulic lift is based on the ratio of the areas of the pistons.

Mechanical advantage is related to piston areas by the following formula:

$$MA = \frac{\text{load piston area}}{\text{effort piston area}}$$

The mechanical advantage is also related to the movement of the pistons. This is indicated as follows:

$$MA = \frac{\text{distance the effort-force piston moves}}{\text{distance the load-force piston moves}}$$

6. In operating a hydraulic lift, the maximum effort force that can be applied is 10 N. The effort-force piston has an area of 2.5 cm^2. The load-force piston has an area of 10 cm^2.

a. What is the mechanical advantage of the lift?
b. What is the maximum load that can be lifted?
c. If the effort piston is pushed down 8 cm, how far will the load move up?

Compare your responses with those in the Appendix on page 89.

In the next investigation you are to imagine a special hydraulic lift. The lift is to be so "strong" that you would be able to lift a minivan by yourself. You will be able to do the lifting just by standing on one of the pistons—the small one, naturally. You will try to predict and calculate some quantities needed to design the lift. These quantities will involve piston areas, forces at each piston, and masses at each piston.

To make your predictions you will have to use the idea that the pressure at the pistons is the same. From this equality, it turns out that the ratio of the two areas of the pistons is equal to the ratio of the two forces at each piston.

$$\frac{\text{area of large piston}}{\text{area of small piston}} = \frac{\text{force at large piston}}{\text{force at small piston}}$$

Of course, that also means the ratio of the two areas is equal to the ratio of the masses on each piston.

$$\frac{\text{area of large piston}}{\text{area of small piston}} = \frac{\text{mass on large piston}}{\text{mass on small piston}}$$

You should now be able to design a hydraulic lift that would support a minivan using just your weight.

Investigation 4F What a Lift!

Refer to the "Think and Link Investigation" on page 310 of the textbook. Read "Think About It," then do the steps under "What to Do."

7. Answer questions 1 and 2 of "Analyze."

Check your answers with your teacher or home instructor.

8. In a hydraulic lift a 1200-N effort force is applied to a piston with an area of 3 m^2.

a. Calculate the pressure placed on the hydraulic lift.

b. What would the generated load force be if this pressure were applied through the hydraulic fluid to a second piston with a 10 m^2 area?

c. What would the generated load force be if this pressure were applied through the hydraulic fluid to a second piston with a 0.5 m^2 area?

Check your answers with your teacher or home instructor.

If you would like to design and build a model hydraulic lift that gives a force advantage, do the next Going Further.

Going Further

Refer to "Problem-Solving Investigation 4G: Build Your Own Hydraulic Lift." This is found on page 311 of the textbook.

The challenge is to design and build a hydraulic system that will allow you to lift a mass close to 1 kg by using a smaller mass. Try to recruit one or two helpers.

If you're using a glue gun, have your home instructor help you with it.

Before building your hydraulic system, get approval for your design from your home instructor.

Note the following tips:

- For the platforms of the modified syringes, 10-cm square pieces of corrugated cardboard may be glued onto the plungers of the syringes. Before using the syringes, test that the platforms are secure.
- If you cannot get support stands and clamps, have a partner hold the syringes in place.
- Lubricate the syringes with vegetable oil or glycerol. The pistons must be able to move freely.

9. To test your understanding of the concepts in this lesson, answer questions 1, 2, and 4 of "Topic 4 Review" on page 312 of the textbook.

Check your answers with your teacher or home instructor.

Looking Back

In this lesson you investigated how hydraulic systems apply Pascal's law. You calculated the pressure and mechanical advantage of hydraulic devices.

Turn to Assignment Booklet 4A. Complete questions 1 to 4 from Section 2.

Lesson 2: Hydraulics and Pneumatics

Cycling up a mountain trail is hard work, but once at the top you have a spectacular view. On the trail, the air inside the tires helped absorb the bumps in the trail—holes, roots, ridges, and rocks.

pneumatic system: a system in which a confined gas is used to transmit or decrease movement or force

The bicycle tires and the air inside them form a **pneumatic system**. Such a system does not transmit movement effectively and therefore is used to absorb shock. The air in the tires is compressible. When a bump pushes the tires inward, the confined air particles are pushed closer together. The result is that your ride is smoothed out.

hydraulic system: a system in which a confined liquid is used to transmit movement or force

If you had water in the bicycle tire, you would be riding on a **hydraulic system**, but your ride would not be smoothed out. That's because the confined water—being incompressible—transmits movement much move effectively than air.

In this lesson you will find that there are many different types of hydraulic and pneumatic systems—each designed for unique challenges. These systems are found not only inside devices produced by people, but also inside the human body.

For a more detailed description of hydraulic and pneumatic systems, turn to the textbook and read page 313 and pages 316 and 317.

1. Study the jackhammer diagram carefully in Figure 4.37 on page 316. What does the compressed air push in to force the chuck down?

2. Do "Pause and Reflect" on page 317 of the textbook.

3. Why do many pneumatic devices require a compressor or a pump to function efficiently?

Compare your responses with those in the Appendix on page 90.

In Module 1 you completed "Design Your Own Investigation: Compression of Liquids and Gases" from page 81 of the textbook. You may want to look back at this investigation, where you compared the compression of water and air in response to applied pressure.

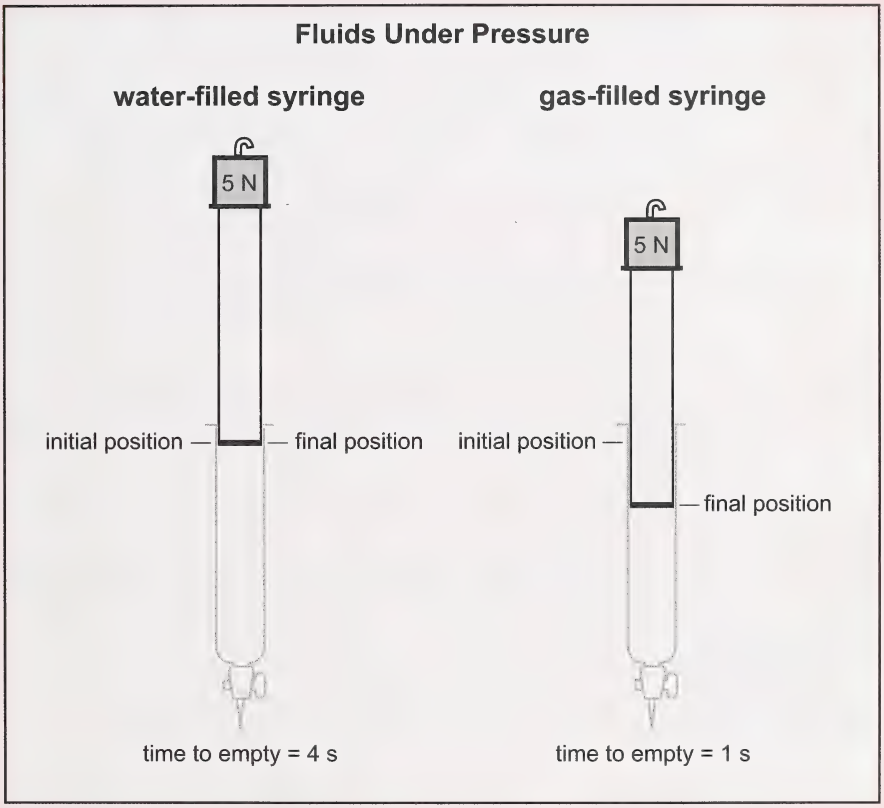
In the next investigation you will compare how liquids and gases respond to the same amount of pressure on confined fluids.

Investigation 4H Comparing Pressure Exerted on a Gas and on a Liquid

Read the "Inquiry Investigation" on pages 314 and 315 in the textbook.

Rather than physically following the steps of "Procedure," you may use the information in the following diagram for your analysis.

Note: Recall from Module 1 that *viscosity* is the measure of the resistance of a fluid to flow or the "thickness" of the fluid.



4. Answer questions 4 to 6 from "Analyze" and "Conclude and Apply."

Compare your responses with those in the Appendix on page 91.

Going Further

Can you think of any other common or unusual pneumatic devices? Are you interested in how they work? Try the "Internet Connect" on page 317 of the textbook. You may make your presentation to your teacher or home instructor.

Pneumatics at Work

The next activity lets you build and test your own pneumatic device—a model hovercraft. To prepare for the activity, turn to page 318 of the textbook and read "Riding on Air." Carefully study Figure 4.43.

For more information about hovercraft, play the *Science 8 Multimedia* CD on a computer. Select the title "Reducing Friction."

Find Out Activity **Build a Model Hovercraft**

Refer to the activity on page 319 in the textbook.

Carry out the steps of "Procedure."

Instead of a spool, you may be able to use a small funnel. The top, curved section cut from a plastic soft-drink bottle may also work.

An adult should do any necessary cutting of the soft-drink bottle.

You may have to experiment with your design to make your model hover consistently.

Discuss ideas with your teacher or home instructor.

5. Answer the "What Did You Find Out?" question.

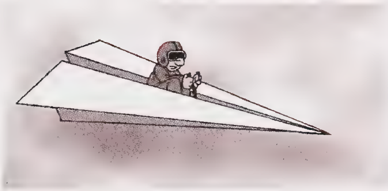
6. Why is the "skirt" necessary to the operation of a hovercraft?

Compare your responses with those in the Appendix on page 91.

Going Further

Hovercraft are noisy but fascinating vehicles that can travel over land or water. Use the "Internet Connect" on page 319 of the textbook to help you find out more about these versatile vehicles.

Hydraulics at Work



Look at the imaginary, single-passenger paper airplane. If only flight could be this simple!

Real airplanes are complex machines; they depend on many hydraulic systems to carry out the commands from the cockpit. You don't have to fly a jumbo jet to make use of hydraulic systems. If you have used running water or a water pistol or been a passenger in a motor vehicle, you have used a hydraulic system.

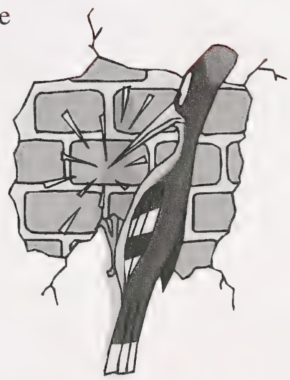
On pages 320 to 322 of the textbook you will find details of complex machines that use hydraulic technologies to carry out tasks. Read the information and then answer the following questions.

7. How is the necessary fluid pressure directed and maintained in high-force hydraulic devices?

8. How does the design of the hydraulic systems on the Airbus A340 prevent a loss of control during engine failure?

Compare your responses with those in the Appendix on page 91.

Hydraulic and Pneumatic Systems in Your Body



A woodpecker usually hammers into wood. Can you imagine seeing a woodpecker hammering into a brick wall? If you witnessed this, you might say the bird had holes in its head.

It turns out that all woodpeckers actually do have holes in their heads—even woodpeckers that stay away from brick walls. These holes, which are air filled, are called sinuses. The sinuses act as pneumatic shock absorbers.

Some of your body systems are natural hydraulic and pneumatic systems. Two of these essential systems, your circulatory and respiratory systems, are described on pages 323 to 325 in the textbook. Read this information. You could also review the related material in Modules 1 and 2.

9. Define *valve* and *pump*.

10. Is your urinary system a hydraulic system or a pneumatic system? Explain.

11. Describe how blood is moved in only one direction through the veins.

Compare your responses with those in the Appendix on page 91.

12. To test your understanding of the concepts in this lesson, answer questions 1, 3, and 6 from "Topic 5 Review" on page 325 of the textbook.

Compare your responses with those in the Appendix on page 92.

Looking Back

Airplanes use both pneumatic and hydraulic systems. In this lesson you investigated the characteristics of gases and liquids that allow their use in pneumatic systems and hydraulic systems. You identified the use of pneumatic and hydraulic systems in a variety of places.

Turn to Assignment Booklet 4A. Complete questions 5 and 6 from Section 2.

Lesson 3: Combining Systems

In previous lessons of this module, you found that many common mechanical devices consist of a combination of simple machines. For example, you could find gears, wedges, screws, and wheels and axles in a lawnmower. You wouldn't be surprised, then, that most machines consist of several **subsystems** composed of simpler parts.

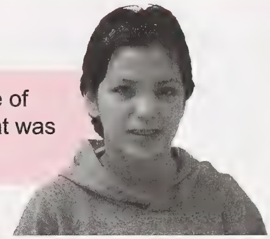
subsystem: a system (made from two or more components) that contributes to the operation of a larger system

The textbook focuses on the design and operation of an automobile braking system and a backhoe. Read pages 326 and 327 of the textbook. Pay particular attention to the identification of the simple machines that make up each system and subsystem.

1. Examine Figure 4.52B on page 326. What type of system are the brakes—hydraulic or pneumatic?

2. a. Classify at least two simple machine components of the brake system.
   b. Is the brake system a subsystem? Explain.

Compare your responses with those in the Appendix on page 92.



The terms *system* and *subsystem* remind me of the levels of organization of living things. That was back in the module on Cells and Systems.

Yes, in picking out a subsystem within a system you are identifying a lower level of organization. For a complex machine, a subsystem is a group of parts—making up just part of the machine—that carries out a specific function.

So, a car radio is a subsystem of the whole car. It has a specific function—to play a radio station of my choice.

You're right. But, if the radio could be pulled out of the dashboard and work as a portable radio, then the radio—on its own—would no longer be considered a subsystem. The context is important in recognizing the level of organization.

The idea of a system and a subsystem is important in analyzing complex machines. If you only see a complex machine as a collection of small parts, it's hard to make sense of the design and operation of the whole machine.

Going Further

Finding subsystems within complex machines and systems can be interesting. Find out more through the "Internet Connect" on page 327 of the textbook.

Read about a career in mechanical engineering on page 330 of "Across Canada."

In the next investigation you get to analyze a fanciful machine. You will also use your creativity to design your own outlandish mechanical device. Your design may be a bit unbelievable, but it should demonstrate linkages and the operation of simple machines. Have fun as you stretch your imagination and apply your understanding of mechanical systems.

Investigation 4I How Silly Can It Be?

Refer to the "Decision-Making Investigation" on page 328 in the textbook.

Read "Think About It" and carry out the steps under "What to Do." Your objective is to design a ridiculously elaborate but scientifically correct mechanical device for an intended task. Your machine must transfer energy through an unbroken chain of events to perform a specific function.

3. Answer questions 1 to 3 from "Analyze." Use diagrams as well as written descriptions in question 2. Have family or friends and your home instructor participate in question 3.

4. List the energy transfer sequence for your machine.

Check your answers with your teacher or home instructor.

Going Further

You may choose either or both of the following activities:

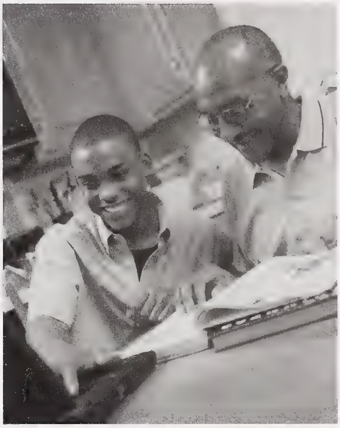
- Put your plans into action! Build your ridiculous device! Try question 4 of "Investigation 4I" on page 328 of the textbook. To ensure appropriate safety and supervision, be sure to check your plans, materials, and techniques with your teacher or home instructor before starting.

- Carefully read the instructions and specifications of "Investigation 4J" on page 329 in the textbook. Then design a robotic arm that meets the specifications. You should discuss your design with your instructor, friends, and family members. Build and test your design if you have access to the necessary materials and any required assistance. Ask your teacher or home instructor to check the safety of your design. Only build your device after it is approved.

5. To test your understanding of the concepts in this lesson, answer questions 1 and 2 in the "Topic 6 Review" on page 330 of the textbook. **Note:** You don't need to draw a diagram in question 2.

Check your answers with your teacher or home instructor.

Looking Back



Simple to complex; practical to ridiculous. In this lesson you focused on complex mechanical systems and subsystems composed of simple machines and hydraulic and pneumatic systems. You designed and perhaps built at least one complex device of your own. You may have used the Internet to further explore machines.

Section Review

To review the concepts covered in this section, turn to page 331 in the textbook and answer questions 1 to 4, 7, 9, and 10 from "Wrap-up Topics 4 to 6."

Check your answers with your teacher or home instructor.

Conclusion

In this section you investigated the application of Pascal's law. You related the characteristics of gases and liquids to their use in hydraulic and pneumatic systems. You found similarities—of structure and function—in biological and mechanical hydraulic and pneumatic systems. You also found out that complex devices consist of simpler, interdependent components and subsystems. You calculated the pressure and mechanical advantage of hydraulic devices and designed a complex machine of your own.

The next time you watch road-construction machines, you will have a better understanding of how they work. Knowing the role of pneumatic systems and hydraulic systems allows you to understand how large-scale movement and great force can be produced.

Turn to Assignment Booklet 4A. Complete questions 7 to 10 from Section 2.

Section 3

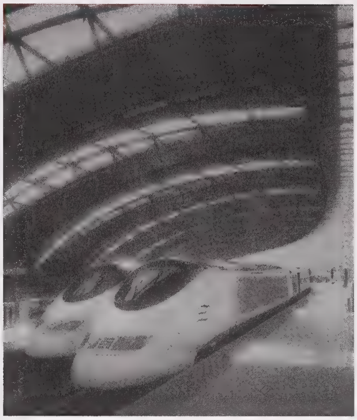
Machine Technology and Society

People have walked on the Moon and in space. What will tomorrow bring? Will travel in space progress to interplanetary travel?

Look back at some inventions that took place in the 200-year period before the first journey into space. The year 1814 saw the first steam-powered locomotive. The internal combustion engine was invented in 1858. The year 1885 saw the first useful automobile—it had an internal combustion engine. In 1903, the first airplane flew. The first Model T car was sold in 1908. The hovercraft appeared in 1956. Meanwhile, there was rapid technological development in many other fields.

What effects did inventions like these have on society, the environment, and the world? Were they all for the better? You will look at some of these effects.

Lesson 1: Machines Throughout History



The trains of today don't look like the trains of the past. Early trains were powered by steam engines, which were not efficient users of energy. Yet, the development of the steam engine was very important because it marked the beginning of a period of rapid change. These changes not only affected the way people travelled, but they changed the way things were manufactured.

In this lesson you will focus on the development of engines and other machines that produce power. You will also use scientific principles to explain how these machines work.

Read page 332 of the textbook to see how steam engines were used in transportation. Think about the questions posed under Figure 4.55 on page 333.

1. List two major changes brought about by the invention of the steam engine. Include examples.

2. Suggest a technological reason why people might have felt about travel as noted in "Off the Wall" on page 332.

Compare your responses with those in the Appendix on page 92.

In the following activity you will look at how science and technology have influenced transportation throughout history.

Find Out Activity Travelling Time

Refer to the activity on page 333 in the textbook. Carry out the steps of "Procedure." Try to use a variety of transportation modes.

3. Answer the "What Did You Find Out?" questions.

Compare your responses with those in the Appendix on page 92.

Putting Steam to Work

You are familiar with the use of pistons in hydraulic and pneumatic devices. In a steam engine, compressed steam is used to apply force to a piston. The motion of the piston is usually transformed into rotary motion to drive machinery. Later, steam turbines eliminated the need for this transformation. Steam "engines" became more efficient and versatile.

Read pages 334 to 337 of the textbook for details of the development of steam technology and its link to electric power generation.

4. What is the function of an exhaust valve in steam technology?

5. Hot-air transportation is based on the idea that "hot air rises." Explain by using the concepts of buoyancy and density.

6. Describe the energy pathway in a steam engine.

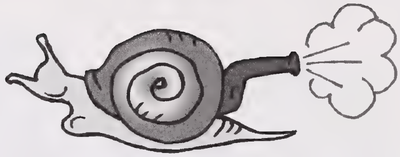
7. How do stationary blades increase turbine efficiency?

Compare your responses with those in the Appendix on page 93.

Going Further

If you are interested in watching steam at work, you can try "Find Out Activity: Build a Model Steam Turbine," on page 337 in the textbook.

Burning Inside



Imagine being a snail. You would not travel very far nor very fast—life would move at "a snail's pace."

People's desire to go farther and faster helped push the development of engine technology. The efficiency and smaller size of the internal combustion engine changed transportation.

Read pages 338 and 339 in the textbook to learn about the significance to transportation of the internal combustion engine.

8. When was the first practical internal combustion engine developed?

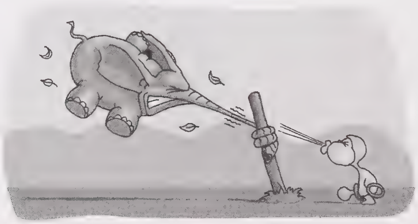
9. List the four strokes that make up a single cycle for a piston in an internal combustion engine.

10. How is the back-and-forth motion of the pistons converted to rotary motion in an internal combustion engine?

Compare your responses with those in the Appendix on page 93.

Going Further

Carry out the "Internet Connect" activity on page 339. Create a list of facts and/or illustrate them in a poster.



That baby can sure blow up a storm. Imagine an elephant having to hold on for dear life in the face of such a blast! Most winds would not be able to lift an elephant off the ground.

However, wind along specially curved wing surfaces can create a huge upward force—enough to get a 300-tonne loaded jumbo jet into the air. This upward force, called **lift**, makes air travel possible.

lift: the upward force created by a flow of air over and around a surface

In the next activity you will explore the relationship between moving air, air pressure, and lift.

Find Out Activity Against the Wind

Refer to the activity on page 340 in the textbook.

Carry out the steps of "Procedure."

11. Answer questions 1 to 3 from "What Did You Find Out?"

Compare your responses with those in the Appendix on page 93.

Timelines in Technology Development

innovation: the introduction of a new thing or a new way of doing something

Innovation is often the result of human needs or wants. The need for water has led to the innovation of technologies to obtain and deliver water. Figure 4.63 on page 340 in the textbook illustrates a number of technologies used to access water.

12. Identify a simple machine component for each of the systems shown in Figure 4.63.

Check your answers with your teacher or home instructor.

Going Further

You may enjoy doing one of the following:

- Water is a basic need. Do the “Pause and Reflect” activity on page 340 in the textbook to learn more about innovative devices used to collect water.
- You can do research on a task, machine, or mechanical system of your choice. Follow “Find Out Activity: Time for a Change?” on page 341 of the textbook. You may find it helpful to discuss your ideas with your teacher or home instructor before starting your research. Older family members or friends may be good sources of information.

In developing technological devices, science concepts are useful. For example, in designing a hydraulic lift, Pascal’s law can be applied—the lift can be made to provide a certain mechanical advantage. Pascal’s law can also be used to predict the strength needed for the wall enclosing the hydraulic lift.

Imagine not knowing about the behaviour of enclosed fluids. Then you would have to make the hydraulic lift by trial and error. You’d make a lift, try it out, and see if it worked. If it didn’t, you’d build another one and so on. It would be better to use the science concepts available to lessen the time needed to get the hydraulic lift right.

In making a paper airplane, trial and error comes in handy and saves you from having to know much about Bernoulli’s principle. In fact, development through trial and error is important when the science behind a technological device is not available.

Development through trial and error includes these steps:

- a field test or trial
- a product failure during the trial
- a design change in response to the failure

Advances in science are important to the development of technology, but technology can develop on the basis of trial and error. Advances in technology usually involve the application of both science and trial-and-error methods.

13. To test your understanding of the concepts in this lesson, answer questions 2 to 5 of “Topic 7 Review” on page 341 of the textbook.

Check your answers with your teacher or home instructor.

Looking Back

In this lesson you studied the history of engines and turbines. You also looked at the resulting changes in temperature. You used the effect of heating on volume and pressure to explain how engines and turbines work.

Turn to Assignment Booklet 4B. Complete questions 1 to 4 from Section 3.

Lesson 2: People and Machines

Look around your home. Do you see machines that will wash and dry clothes? Do you see a machine that can keep things cold and frozen and, perhaps, even make ice cubes? If you have a clothes washer, a clothes dryer, and a refrigerator you have all these things! Scientific and technological innovations have provided great benefits.

What are the costs that come with the benefits of these machines? Do you know of machines in your home and your community that have an effect on the global environment? Is this effect significant? In this lesson you will examine such questions. You will look at how the Industrial Revolution led to large-scale societal and environmental changes. You will consider some questions about the future.

Consequences

Read page 342 of the textbook. It describes the automobile as an innovation that has many positive and negative side effects that were not foreseen. It also poses questions you should ask about the machines in use today and in any future technological developments.

1. Why is Freon 12 no longer used as a coolant in refrigerators and air conditioners?

2. Vehicles need roads and roads need space. Think about a large city and its surrounding area. (You may refer to Figure 4.66 on page 344 of the textbook.)

  a. Give at least two negative effects that roads and vehicle traffic must have on the global environment.

  b. Name one environmentally friendly transportation development that has resulted from the increased size of cities.

  c. Suggest two ways commuters could be more environmentally responsible.

3. Do "Pause and Reflect" on page 342.

Check your answers with your teacher or home instructor.

The Industrial Revolution and Society

revolution: a sudden, drastic change

The invention of the steam engine in the 18th century started a **revolution**—the Industrial Revolution. This revolution caused many changes in the way things were produced and where people gathered to work.

The Industrial Revolution touched many people's lives. For example, if you were a weaver living in the early 1700s, you probably used a simple loom and worked out of your own home. You may have lived in a small, quiet village. But then along came steam-driven looms. These had to operate near their source of power and it was natural to have these looms organized together in factories. The powered looms could be used to weave cloth more cheaply than manual looms. The new factories drove down the price of cloth so that weaving from home was no longer feasible. By the end of the 1700s, most weavers worked in factories. Most people lived in towns and cities where these factories were built.

For more details, turn to page 343 of the textbook and read "The Industrial Revolution."

4. The steam engine was one significant change that transformed the manufacture of goods in the late 1700s. What was the second significant development?

5. Define *mass production*.

6. How did the Industrial Revolution change where people lived?

Compare your responses with those in the Appendix on page 93.

Going Further

What was life like in the early years of the Industrial Revolution? Use your imagination and/or do some research as you try the "Pause and Reflect" on page 343 of the textbook.

Interrelated and Interdependent

The automobile is perhaps the machine that has the greatest impact on your world. Read pages 344 and 345 in the textbook. Find out how the automobile has changed society and the environment, and how societal and environmental concerns have changed the automobile.

7. Figures 4.67 and 4.68 in the textbook show cars from different eras. Name one or two obvious differences. Explain why you think these changes took place.

8. List two major environmental changes and two major societal changes related to the development of the automobile.

9. Today, most cars use gasoline as a source of energy. What are other new sources of energy that are being tried for cars?

Compare your responses with those in the Appendix on page 93.

Going Further

Do you have an interest in the future, your environment, possible careers, or technological developments? Try the "Internet Connect" on page 345 of the textbook.

If you're interested in hydrogen-fueled vehicles and other energy-related material, visit "Fuel Cells and Energy: Cool Car, Clean Future" at this address:

> **http://www.gm.com/company/gmability/edu_k-12/5-8/fc_energy/autonomy_hywire_011303.html**

Using train transportation in Canada has declined in favour of faster but less energy-efficient modes of moving goods and people. Are the benefits worth the costs?

There are more big trucks on the roads. Road building and maintenance is an issue. Solar-powered and electrical vehicles are generally considered to be environmentally friendly. Such vehicles produce no harmful emissions. However, the production of the batteries required to run these vehicles could create a pollution problem as great as the one produced by the emissions from the vehicles currently in use. Also, charging electrical vehicles requires a power source. Power plants can have their own negative impacts on the environment.

SOLAR VEHICLE PROJECT/UNIVERSITY OF ALBERTA

Think about the type of questions that need to be asked and answered when designing a new technology or improving an existing one as you read page 346 in the textbook. You will find these questions useful as you do the next investigation.

In the next investigation you will assess a mechanical device from various perspectives. Get two bicycles that you can compare and evaluate.

Investigation 4K The Real Costs

Refer to the "Think and Link Investigation" on page 347 in the textbook.

Fingers and hair can get caught between a bicycle's chain and sprockets. Keep your hands and hair away from moving parts.

Carefully read "Think About It." Carry out the steps under "What to Do." You may choose to work alone or with your family, your friends, or your home instructor. Be sure to take into account the production (mining of the ores, paint and plastic production, and transportation of the components and the completed structure) and the disposal of your bicycle. You will need access to two different bicycles.

10. Answer both questions from "Analyze."

Check your answers with your teacher or home instructor.

The environment, society, technology, and science are all interconnected. Changes in one area often stimulate change in the others. Positive change in one area can create an unexpected and/or negative change in another. It is important that people learn to evaluate the need for change and the possible short-term and long-term results of change. Is the proposed change truly an improvement? Are there other options that might have a better impact? A wide variety of assessment factors must be considered when change is being planned.

These assessment factors include the following:

- function
- use of materials
- durability
- environmental impact
- societal impact
- safety
- efficiency
- effectiveness
- design
- cost
- energy source(s)

People-Friendly Designs

The science of ergonomics provides the knowledge needed to design technological devices so that they can be used safely, effectively, and comfortably. Read pages 348 and 349 of the textbook to learn more about this science.

11. How does an air mattress make sleeping on the ground more comfortable than sleeping on a hard surface?

12. List six positive changes that give disabled people greater freedom. **Hint:** Consider designs of wheelchairs and buildings.

Compare your responses with those in the Appendix on page 94.

Going Further

Do you need a reminder of the relationship between force, area, and pressure and how it affects your comfort?

Try "Find Out Activity: Flat Out" on page 348 in the textbook.

13. To test your understanding of the concepts in this lesson, answer questions 1, 2, 5, and 6 of "Topic 8 Review" on page 350 of the textbook.

Check your answers with your teacher or home instructor.

Looking Back

Do you think the costs of modern machines are worth the benefits? Would you want a return to the simpler way of life, as in "pioneer times"? Can you influence the decisions society makes to balance the costs and benefits of technological change? There is much you will have to think about. The more you know about the costs and benefits of technological change, the more positive your influence and impact can be.

Section Review

To review the concepts covered in this section, turn to page 351 in the textbook and answer questions 5 and 10 from "Wrap-up: Topics 7 and 8."

Check your answers with your teacher or home instructor.

Conclusion

In this section you traced technological development relating to mechanical devices—especially machines associated with transportation. You saw that technological development, supported by advances in scientific knowledge, was largely driven by societal needs or wants. In turn, technological development had an impact on society and the environment. The benefits of new technology sometimes brought along unintended consequences—some of which were adverse.

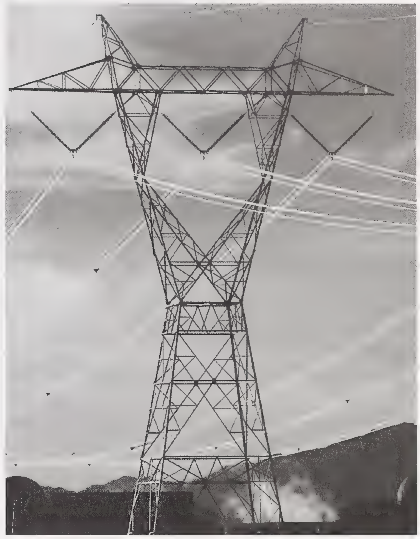
Going Further

Are you a potential inventor or entrepreneur? Do you know someone who faces physical challenges? Would you like to get started on a career in ergonomics? Turn to the "Unit 4 Project: Adapting Tools" on pages 354 to 355 of the textbook. You may wish to share your invention with someone who is physically challenged.

Turn to Assignment Booklet 4B. Complete questions 5 to 8 from Section 3.

Module Summary

In this module you discovered that mechanical devices perform functions by controlling motion or by transferring one form of energy to the energy of motion. Machines make work easier to perform by providing a force advantage or a speed advantage. Simple machines, hydraulic systems, and pneumatic systems are linked to form complex machines. You compared mechanical devices to see how designs changed over time. You evaluated mechanical devices and based your evaluation on how efficiently energy is used and how effectively functions are carried out. You also considered the impact of machines on daily life, the community, and the environment.



Electrical energy comes down the power lines and into your community. This energy supports a modern lifestyle. Imagine life without electricity. Without electricity you wouldn't have a vaccuum cleaner, a dishwasher, a washing machine, a clothes washer, and so on. These home appliances represent benefits in your daily life. The power plant that provides the electricity for these appliances may also create pollution—one of the costs of technology. To make responsible decisions relating to technology, you have to be aware not only of the benefits to you but also the costs. These costs may be widespread.

Module Review

Turn to pages 356 to 359 in the textbook. Review the concepts listed under "Unit at a Glance." To help test your understanding of concepts covered in this module, answer questions 1, 4, 6, 13, 19, 21, 22, 27, 30, and 31.

Check your answers with your teacher or home instructor.

Turn to Assignment Booklet 4B and do the Final Module Assignment.

SCIENCE 8

APPENDIX

Glossary

Suggested Answers

Mechanical Device Rules

Gear Templates

Image Credits

Glossary

closed system: a self-contained system; a system separated from the surroundings by a barrier

compound pulley: a combination of two or more pulleys (fixed and movable) working together

crankshaft: a shaft that turns or is turned by a crank

Pistons turn a car's crankshaft, which then turns the wheels.

driven gear (follower): the gear moved by the driving gear

driving gear (driver): the gear to which the effort force is applied

efficiency: the ratio of output work of a machine to input work usually expressed as a percentage

Note: An easy way to remember the formula is "Oh," "I" remember the formula for efficiency.

$$\text{Efficiency} = \frac{\text{output work}}{\text{input work}} \times 100\%$$

effort arm: the part of a lever that extends from the fulcrum to the point at which the effort force is applied

effort force (F_E): the force applied to a device or system to move a mass; the force required to do work

energy: the ability of a substance or a system to do work

Energy exists in several forms (chemical, kinetic, mechanical, thermal, and so on).

ergonomics: the science of designing machines, tools, and work areas to best suit the human body

exhaust valve: a movable part that releases spent (used, waste) gases

fixed pulley: a stationary pulley attached to a rigid support

force: a push or pull

force advantage (*FA*): the advantage provided by a machine that makes the required effort force less than the load force

A machine that has a mechanical advantage greater than 1 provides a force advantage.

fulcrum: the pivot point that supports a lever

gear: a wheel with cogs or teeth around its rim

gear train: two or more meshing gears used to transfer motion and force

hydraulic lift: a closed mechanical system that uses a liquid under pressure to multiply force

hydraulic system: a system in which a confined liquid is used to transmit movement or force

hydraulics: the study of pressure in liquids

hydrogen fuel cell: a cell in which hydrogen fuel and oxygen from the atmosphere combine to produce electricity

inclined plane: a sloped surface that reduces the effort force needed to raise an object to a new level (lower force over a greater distance)

input work: the work done on a machine to move a load

innovation: the introduction of a new thing or a new way of doing something

internal combustion engine: an engine that burns fuel within the engine rather than in an external furnace like a steam engine

joule (J): a unit of work or energy equal to the work done by a force of one newton acting through a distance of one metre

One joule is equivalent to one newton-metre. That is, 1 J = 1 N•m.

kilopascal: a unit of pressure equal to 1000 Pa

kinetic energy: the energy an object or system has due to its motion

lever: a simple machine consisting of a rigid bar that pivots on a fulcrum

lift: the upward force created by a flow of air over and around a surface

linkage: a device that transfers energy from one object to another within a system (for example, a belt, chain, gear, lever, or rope)

load: the mass to be moved

load arm: the part of a lever that extends from the fulcrum to the point at which the load is applied

load force (F_L): the force applied to a device or system by the mass that is being moved

machine: a mechanical device that allows you to do mechanical work more easily or more conveniently

mass: the quantity of matter in an object

mass production: the large-scale manufacturing of standardized products

mechanical advantage (*MA*): the ratio of the load force to the applied force in using a machine

$$MA = \frac{\text{load force}}{\text{effort force}}$$

movable pulley: a pulley suspended on a rope or cable that moves with the load

output work: the work done by a machine on a load

pascal (Pa): a unit of pressure equal to the pressure of 1 N of force applied over an area of 1 m^2

One pascal is equivalent to one newton per square metre. That is, 1 Pa = 1 N/m^2.

Pascal's law: a law that states pressure applied to one part of a confined fluid is transmitted equally in all directions throughout the fluid

piston: a movable disc that fits snugly inside a cylinder

pneumatic system: a system in which a confined gas is used to transmit movement or force

pneumatics: the study of pressure in gases

potential energy: stored energy; the energy an object or system has due to its position or condition; includes gravitational and chemical potential energy

power: the rate of doing work or producing or consuming energy

The watt is a unit of power.

pressure: force per unit area

The pascal is a unit of pressure.

pulley: a simple machine made of a wheel with a grooved rim that guides a rope

A pulley is used to decrease effort force or change the direction of the force.

pump: a device that applies a force to move fluid within a system

screw: an inclined plane wrapped around a cylinder or cone

simple machine: a basic tool or device that transfers energy to do useful work

The six simple machines include the lever, inclined plane, screw, pulley, wheel and axle, and the wedge.

speed: the rate of motion expressed as distance travelled per unit time (for example, m/s, km/h)

speed ratio: the relationship between the speed of the effort force and the speed of the load force

The speed ratio for gears is the ratio of the speed of rotation of the driven gear to the speed of rotation of the driving gear.

speed advantage (*SA*): the advantage provided by a machine that makes the load move faster than the effort force

The mechanical advantage is less than 1 for a machine providing a speed advantage.

sprocket: a gear that drives a chain or is driven by a chain

subsystem: a system (made from two or more components) that contributes to the operation of a larger system

system: a combination of several components or subsystems that work together to perform a specific function

transmission: transfer from one place to another without a change in form

valve: a device that controls the movement (speed, direction, and/or volume) of a fluid within a system

wedge: a single or double-sided ramp that is forced into or under an object (its most common use is cutting)

weight: the force of gravity exerted on a mass

wheel and axle: a type of simple machine made up of two turning objects attached at their centres

work (*W*): a transfer of energy from one object or system to another when a force is applied over a distance

The amount of work is equal to the product of the force and the distance.

$W = Fd$

Suggested Answers

Section 1: Lesson 1

1. A lever is a simple machine consisting of a rigid bar that pivots on a fulcrum.

   A fulcrum is the pivot point that supports a lever.

   An effort arm is the part of a lever that extends from the fulcrum to the point at which the effort force is applied.

   A load arm is the part of a lever that extends from the fulcrum to the point at which the load is applied.

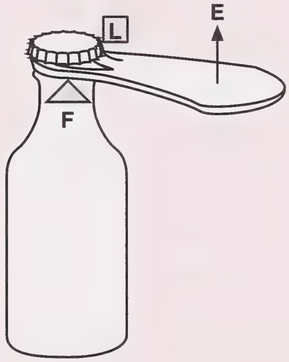
   Load is the mass to be moved.

   Load force (F_L) is the force applied to a device or system by the mass that is being moved.

   Effort force (F_E) is the force applied to a device or system to move a mass—it's the force required to do work.

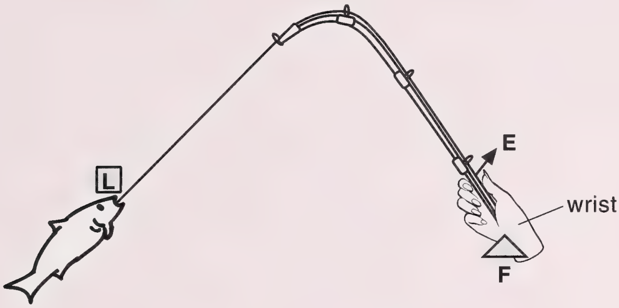
2. **Textbook question 1 from "Topic 1 Review," page 284:**

   The bottle opener is a Class 2 lever because the load is between the effort and the fulcrum.



The crowbar is a Class 1 lever. The lid (and dog) is the load. The fulcrum is the top edge of the front of the box. The effort force is applied to the handle. The fulcrum is between the load and the effort force. Therefore, the crowbar is a Class 1 lever.

The fishing rod is a Class 3 lever since the effort is between the load and the fulcrum.



3. Textbook question from "Did You Know?" page 271:

The canoe paddle is a Class 3 lever. The top hand serves as the fulcrum. The lower hand, part way down the paddle, applies the effort force. The water at the bottom end of the paddle serves as the load. With the effort force between the fulcrum and the load, the paddle is a Class 3 lever.

6. a. If you don't move the apple, you aren't doing scientific work. You are applying a force, but the force is not applied through a distance.

b. In this case you are applying a force upwards, **and** the load is moving in the direction of that force. You are doing work in scientific terms.

7. a. Work = force × distance

$$\begin{aligned} W &= Fd \\ &= 6\ \text{N} \times 0.20\ \text{m} \\ &= 1.2\ \text{N}\bullet\text{m} \\ &= 1.2\ \text{J} \end{aligned}$$

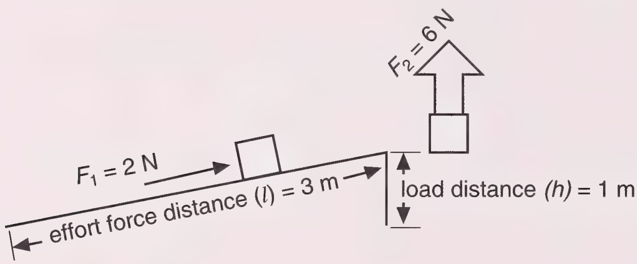
The lever does 1.2 J of work on the brick.

$$\begin{aligned} W &= Fd \\ &= 500\ \text{N} \times 0\ \text{m} \\ &= 0\ \text{N}\bullet\text{m} \\ &= 0\ \text{J} \end{aligned}$$

You did not do any work on the wall because the wall did not move. The force was not exerted over any distance.

8. If you ignore friction, the amount of work you do will remain the same for a particular job. The length of the ramp will not affect the amount of work you do. **Note:** You may wish to look at "Mechanical Devices Rules" in the Appendix for help with your predictions.

Note: The following example shows how the quantities of work compare.



Consider the ramp to be frictionless.

Check to see that the work done in pushing the load up the ramp is equal to the work done in lifting it:

LS	RS
Work done by F_1	Work done by F_2
$F_1 \times l$	$F_2 \times h$
$2 \text{ N} \times 3 \text{ m}$	$6 \text{ N} \times 1 \text{ m}$
6 N•m	6 N•m

LS = RS

The quantity of work done is the same whether sliding the load up the ramp or directly lifting it.

12. People use machines to make work easier by

- reducing the effort force required to move the load
- increasing the speed at which the load moves
- changing the direction of the force

13. **a.** The energy source has been the chemical and mechanical (kinetic energy of a mechanical device) energy of the human body.

b. Other energy sources include

- hemical energy stored in batteries and fossil fuels such as wood and coal
- electrical energy
- elastic or gravitational potential energy
- chemical and mechanical energy provided by work animals
- solar energy
- kinetic energy of moving air (wind)

14. While the amount of work is about the same, the effort force that must be applied is very different. It is well beyond *most* people's capacity to exert enough effort force to lift even a small car.

15. **a.** The greater the mechanical advantage, the *less* the effort force is compared to the load force.

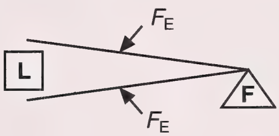
    b. Suppose you move a load with a machine with $MA > 1$. This allows F_E to be *less than* F_L, the weight of the load. The machine is providing a *force* advantage.

    c. Any machine with $MA < 1$ requires F_E to be *greater than* F_L, the weight of the load. However, this machine is likely providing a *speed* advantage.

    d. Any machine with MA = 1 requires F_E to be *equal to* F_L.

    e. The longer the effort arm, the *less* the effort force needed to move the load.

16. Tweezers are made from two Class 3 levers joined at the fulcrum. The effort force is in the middle.



A Class 3 lever has a $MA < 1$.

18. Textbook questions 2 to 5 from "Topic 1 Review," page 284:

2. Work = force × distance

$$\begin{aligned} W &= Fd \\ &= 60\,000\ \text{N} \times 1.5\ \text{m} \\ &= 90\,000\ \text{J} \\ &= 90\ \text{kJ} \end{aligned}$$

You must do 90 kJ of work to lift the elephant.

3. The effort force will be less when moving the elephant up an inclined plane. But the effort force has to act over a longer distance. (By using a ramp, the elephant can walk up and you wouldn't have to exert any force.)

4.
$$\begin{aligned} MA &= \frac{\text{load force}}{\text{effort force}} \\ &= \frac{20\ \text{N}}{100\ \text{N}} \\ &= 0.20 \end{aligned}$$

The mechanical advantage of the hockey stick is 0.20. **Note:** With a $MA < 1$, this Class 3 lever provides a speed advantage (SA).

5.

$$MA = \frac{\text{effort arm length}}{\text{load arm length}}$$

$$0.20 = \frac{25 \text{ cm}}{\text{load arm length (cm)}}$$

$$\text{Load arm length (cm)} = \frac{25 \text{ cm}}{0.20} = 125 \text{ cm}$$

The hockey stick is 125 cm long.

The ratio of the effort arm length to the load arm length is the same as the ratio of the effort speed to the load speed.

$$MA = \frac{\text{effort arm length}}{\text{load arm length}} = \frac{\text{effort speed}}{\text{load speed}}$$

$$0.20 = \frac{\text{effort speed (km/h)}}{\text{load speed (km/h)}} = \frac{20 \text{ km/h}}{\text{load speed (km/h)}}$$

$$\text{Load speed} = \frac{20 \text{ km/h}}{0.20} = 100 \text{ km/h}$$

Or you can determine the answer this way. The $MA = \frac{1}{5}$, so the effort speed is multiplied by a factor of 5 (the inverse of the mechanical advantage).

Therefore, the puck will move at $5 \times 20 \text{ km/h} = 100$ km/h.

The puck will move at 100 km/h.

Section 1: Lesson 2

1. The handle in a winch acts as the effort arm, the radius of the wheel is the load arm, and the axle is the fulcrum. Since the fulcrum is always between the effort and the load, a winch is like a rotating Class 1 lever.

2. **Textbook questions from "Figures 4.14A and 4.14B," page 286:**

   The effort force in Figure 4.14A is exerted on the pedal and crank system (a wheel) that transmits the force to the axle (which is rigidly fixed to the front tire). The axle applies force to the tire. The clown gains a very slight speed advantage, because the crank system has a slightly smaller radius than the front tire. In one rotation, the load on the outer edge of the tricycle tire moves a bit farther than the effort force on the pedal of the crank.

   In Figure 4.14B, the great difference between the load distance and the effort force distance gives a big speed advantage.

3. Determine the length in the following way.

$$MA = \frac{\text{radius of effort wheel}}{\text{radius of load wheel}}$$

$$MA = \frac{x}{3.5 \text{ cm}}$$

$$MA = 8$$

$$\frac{x}{3.5 \text{ cm}} = 8$$

$$x = 8 \times 3.5 \text{ cm}$$

$$= 24$$

The winch handle should be 24 cm long.

4. The radius of the large wheel would have to be 7 times the radius of the crank. Therefore, the radius of the large wheel would be $7 \times 25 \text{cm} = 175$ cm.

5. A gear is a wheel with cogs or teeth around its rim.

   A gear train is two or more meshing gears used to transfer motion and force.

   The driving gear (driver) is the gear to which the effort force is applied.

   The driven gear (follower) is the gear moved by the driving gear.

   The sprocket is a gear that drives a chain or is driven by a chain.

   A speed ratio for a gear train is the relationship between the speeds of rotation of a driving gear and a driven gear.

6. **a.** The driver gear has 35 teeth. The driven gear has 25 teeth.

   b. With this gear train you will produce a speed advantage (and also a change in the direction of the force). **Note:** The driven gear has a smaller circumference and radius than the driver. Therefore, the driven gear rotates farther.

   c. Using the smaller gear as the driver gear provides a force advantage (and a change in the direction of motion). **Note:** This type of system reduces the effort force required.

   d. Both gears have 35 teeth, so both the effort force and the load will travel the same distance.

   e. The middle gear allows both the effort force and the load to move in the same direction.

9. **a.** You will calculate the speed ratio in the following way.

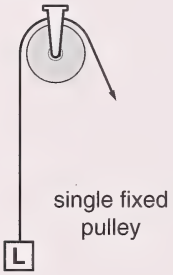
$$\begin{aligned}\text{Speed ratio} &= \frac{\text{number of driver gear teeth}}{\text{number of driven gear teeth}}\\ &= \frac{42}{14}\\ &= 3\end{aligned}$$

The speed ratio for this set of sprockets is 3.

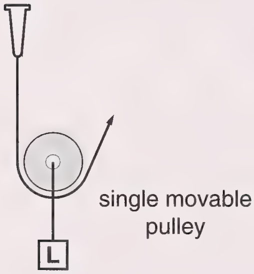
b. The rear wheel will rotate three times for each full rotation of the front sprocket.

c. This gear train provides a speed advantage since the speed ratio is greater than 1.

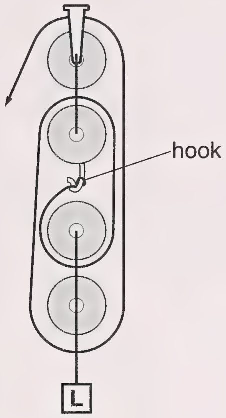
10. A fixed pulley is a stationary pulley attached to a rigid support. It's used to change the direction of the applied force.



A movable pulley is a pulley suspended on a rope or cable that moves with the load.



A compound pulley is a combination of two or more pulleys (fixed and movable) working together. **Note:** A block and tackle is one kind of compound pulley.



11. **a.** You can lift a load of 200 N with a mechanical advantage of 4. The effort force of 50 N is multiplied by a factor of 4.

b. The trade-off for the force advantage is that you will have to pull four times more rope. (The effort force must move four times farther.) The job will take longer but will be much easier.

12. Textbook questions 1 to 3 from "What Did You Find Out?" and "Extension" on page 293:

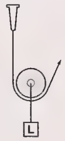
1. Increasing the number of rope windings makes it easier for the student to pull the broom handles together.

2. The students holding the broom handles experience a force pulling them together.

3. As the number of windings increases, the student has to pull the rope farther (but the effort force decreases). The total effect of friction between the rope and the handles increases as the number of windings increases. **Note:** This activity simulates the effect of a compound pulley. The more sections of rope supporting the load, the lower the effort force required to move that load. The lower effort force is balanced by a greater effort force distance. The effort force distance can be determined by measuring the length of the rope that has been pulled to move the load a specific distance.

13. Textbook questions 1 to 4 from "Topic 2 Review," page 295:

1. $MA = 1$ $MA = 2$



Note: Examine the single movable pulley carefully. Notice that the rope segment on one side of the load is attached directly to the "ceiling." You would hold the other segment. Think about it! How would the load's weight be supported? Well, you would support half the weight. The rope attached to the "ceiling" would support the other half. So, your effort force would be equal to one-half of the weight of the load.

2. $MA = \dfrac{\text{effort arm length (cm)}}{\text{load arm length (cm)}}$

$$4 = \frac{\text{effort arm length (cm)}}{5\ \text{cm}}$$

$$= 20\ \text{cm}$$

The effort arm length (handle) would be 20 cm.

3. Counting the number of ropes that support the load gives you the mechanical advantage of this pulley system. There are four supporting ropes (or rope segments). The single fixed pulley is only providing a change in the direction of the effort force. The mechanical advantage is 4.

4. The bicycle would have $2 \times 4 = 8$ gear combinations.

Section 1: Lesson 3

1. Kinetic energy is the energy an object or system has due to its motion.

   Potential energy is stored energy. It's the energy an object or system has due to its position or condition. Potential energy includes gravitational and chemical potential energy.

2. **Textbook question from "Figure 4.26," page 297:**

   The Sun's thermal energy is converted into kinetic energy that causes liquid water to evaporate. When the evaporated water is lifted into the air by convection currents, it gains gravitational potential energy. When it falls as rain, its gravitational energy is converted into kinetic energy.

   The water behind the dam has stored energy. This gravitational potential energy will be converted into kinetic energy, then mechanical energy, and then electrical energy.

3. In energy conversion, energy is changed from one form to another—from potential to kinetic energy, or from electrical energy to light energy, or from chemical energy to energy of motion. In energy transmission, the same form of energy is transferred from one object or system to another—there is no change from one form to another. For example, electrical energy is transmitted from the generating plant to your community along power lines.

4. An ideal machine is frictionless and 100% efficient. The work input equals the work output. A real machine has friction and is less than 100% efficient. The greater the friction and the more components that have to move, the lower the efficiency will be. The work input is **always** more than the work output.

5. Lubricating with oil or grease increases the efficiency of most machines. Friction is a primary cause of loss of efficiency.

6. Here are some examples of useful friction.

- holds up your socks
- allows you to walk
- slows your car down
- keeps your buttons in place
- provides warmth—rubbing your hands together

Perhaps you have other examples.

7. Rust increases friction. The increased friction makes you apply a greater effort force in moving the handles. Because you apply the increased effort force through the same distance as before, you end up doing more work.

8. **Textbook questions 1 to 4 from "Analyze," page 301:**

1. A sample analysis table follows.

Mechanical Advantage of a Compound Pulley		
Trial	**Number of Ropes**	**Mechanical Advantage**
A		
B		

2. and **3.** A sample analysis table follows.

Mechanical Advantage of a Compound Pulley		
Trial	**Number of Ropes**	**Mechanical Advantage**
A	1	0.9
B	2	1.9

4. The manipulated variable is the number of ropes that support the load. The responding variable is the mechanical advantage.

You may also consider the effort force to be the responding variable.

9. **Textbook question 5 of "Conclude and Apply," page 301:**

   5. The mechanical advantage is close to the number of ropes.

      In an ideal compound pulley without a loss of energy due to friction, the mechanical advantage is equal to the number of ropes. **Note:** The theoretical mechanical advantage does equal the number of ropes.

10. **Textbook question 6 from "Extension," page 301:**

Work done by effort force

$$\begin{aligned} W &= Fd \\ &= 1.8\,\text{N} \times 0.15\,\text{m} \\ &= 0.27\,\text{N}\bullet\text{m} \\ &= 0.27\ \text{J} \end{aligned}$$

Work done on load

$$\begin{aligned} W &= Fd \\ &= 8.0\,\text{N} \times 0.03\,\text{m} \\ &= 0.24\,\text{N}\bullet\text{m} \\ &= 0.24\ \text{J} \end{aligned}$$

$$\begin{aligned} \textit{Efficiency} &= \frac{\text{Work done on load}}{\text{Work done by effort force}} \times 100\% \\ &= \frac{0.24\ \text{J}}{0.27\ \text{J}} \times 100\% \\ &= 0.89 \end{aligned}$$

The efficiency of the compound pulley in Trial E is 0.89.

11. **Textbook questions 1 to 3 from "Topic 3 Review," page 302:**

   1. Answers will vary. Compare your answers with the ones given.

Energy Conversion and Transmission	
Energy Converted	**Energy Transmitted**
clock radio: electrical energy to thermal and sound energy	**electrical energy from the generating station to your home**
lamp: electrical energy to thermal and light energy	**kinetic energy from your hand to the switch**
hot-water tank: chemical to thermal energy	**thermal energy of the hot water to the shower head to you**
breakfast: chemical energy of food to kinetic (mechanical) energy in pedalling your bike	**kinetic energy of pedals to the rear sprocket by the chain**

   2. **a.** Efficiency is the ratio of useful output to input work, energy, force, distance, and so on for a device. It is usually expressed as a percentage.

      b. $\text{Efficiency} = \frac{\text{output}}{\text{input}} \times 100\%$

3. Without friction the items or material being transported on the belt would slip. They would not move with the belt. The belt itself would not move without friction between it and the rollers that drive it. Your example of useful friction will vary. Without friction, most structures would collapse. Friction helps stop a ball from rolling. Friction keeps your feet from slipping. Friction keeps a nail in wood.

Section 2: Lesson 1

1. **Textbook questions 1 to 3 from "What Did You Find Out?" on page 304:**

    1. The straight pin required the least amount of force to pop the balloon and it was the quickest method.

    2. The straight pin had the smallest surface area in contact with the balloon.

    3. Each method required the same amount of pressure. The balloon material determines the pressure required to pop the balloon. The pin popped the balloon most easily because it took a lower force on its tiny area to create the required pressure.

2. Pressure is force per unit area.

    A pascal (Pa) is a unit for pressure. One pascal is defined as one newton per square metre.

    One kilopascal (kPa) is equal to 1000 Pa.

3. **Textbook questions from the top "Math Connect," page 305:**

    Your answer may vary. For this example, a weight of 450 N is used as a person's weight. Find the pressure of the boot. The area of the boot is given as 0.05 m^2.

$$\begin{aligned} p_{\text{B}} &= \frac{F}{A} \\ &= \frac{\text{person's weight (N)}}{\text{area of one boot } (\text{m}^2)} \\ &= \frac{450 \text{ N}}{0.05 \text{ m}^2} \\ &= 9000 \text{ N/m}^2 \quad \textbf{or} \quad 9000 \text{ Pa} \quad \textbf{or} \quad 9 \text{ kPa} \end{aligned}$$

Find the pressure of the snowshoe. The area of the snowshoe is given as 0.20 m^2.

$$\begin{aligned} p_{\text{S}} &= \frac{F}{A} \\ &= \frac{\text{person's weight (N)}}{\text{area of one snowshoe } (\text{m}^2)} \\ &= \frac{450 \text{ N}}{0.20 \text{ m}^2} \\ &= 2250 \text{ N/m}^2 \quad \textbf{or} \quad 2250 \text{ Pa} \quad \textbf{or} \quad 2.25 \text{ kPa} \end{aligned}$$

Find the difference in pressure.

$$\begin{aligned} p_B - p_S &= 9000 \text{ N/m}^2 - 2250 \text{ N/m}^2 \\ &= 6750 \text{ N/m}^2 \quad \textbf{or} \quad 6750 \text{ Pa} \quad \textbf{or} \quad 6.75 \text{ kPa} \end{aligned}$$

The difference in pressure is 6750 N/m^2 or 6750 Pa or 6.75 kPa.

Note: The area of the snowshoe is four times bigger. The pressure of the boot is four times greater than the pressure of the snowshoe.

4. Pascal's law is a scientific law stating that pressure applied to one part of a confined fluid is transmitted equally in all directions throughout the fluid, regardless of the container's shape.

   A hydraulic lift is a closed mechanical system that uses a liquid under pressure to multiply force.

   A closed system is a self-contained system that is separated from the surroundings by a barrier.

5. Your body's circulatory system is a closed hydraulic system.

6. **a.** $$\begin{aligned} MA &= \frac{\text{load piston area}}{\text{effort piston area}} \\ &= \frac{10 \text{ cm}^2}{2.5 \text{ cm}^2} \\ &= 4 \end{aligned}$$

   The mechanical advantage is 4.

   b. A mechanical advantage of 4 shows that the effort force is multiplied by 4. Therefore, the maximum load that can be lifted is $4 \times 10 \text{ N} = 40 \text{ N}$.

   c. The speed advantage is the inverse of the mechanical advantage. Therefore, the speed advantage is $\frac{1}{4}$. The load will move $\frac{1}{4}$ the distance of the effort force. So the load will move only $\frac{1}{4} \times 8 \text{ cm} = 2$.

Section 2: Lesson 2

1. Air pressure forces a piston down against the chuck. **Note:** Air compressed by high pressure can transmit large forces very quickly. Air confined under low pressure is used to absorb energy.

2. **Textbook question from "Pause and Reflect," page 317:**

   Some sports shoes have air cells built into their soles to absorb energy.

3. Pneumatic devices used for force transfer (rather than absorption) require a compressor or a pump. Gases must be compressed under high pressure before they can quickly and effectively transmit a force.

4. **Textbook questions 4 to 6 from "Analyze" and "Conclude and Apply," page 315:**

    4. The manipulated variable was the fluid used.

       The responding variable in Step 5 was the final volume of the fluid. In Step 6 the responding variable was the time it takes to empty the cylinder.

       Some controlled variables were the mass used, the initial fluid volume, the size of the stopcocks, and the size of the plungers.

    5. This activity demonstrates the following:

       - Liquids are incompressible (particles are close together).

       - Gases are compressible (there are large spaces between the particles).

       - Liquids have a higher viscosity than gases.

       - Air is much less dense then water. It took a shorter amount of time for fewer particles to leave through the same opening.

    6. The volume of a gas decreases as pressure increases; the volume of liquids remains unchanged under pressure.

5. **Textbook question from "What Did You Find Out?" on page 319:**

   Changes could include

   - the addition of a "skirt" to hold the air under the base more effectively
   - using a balloon with greater volume
   - changing the size of the opening into the balloon

6. The "skirt" confines the air under the hovercraft. This allows air pressure to increase. With a large enough air pressure, there is a large enough force to support the vehicle's weight.

7. Machines use a fluid reservoir, pumps, and valves. The pumps maintain the required fluid pressure and valves direct the fluid into the machine's active components.

8. The various controls are operated by more than one hydraulic system. Each hydraulic system receives power from a different engine. If necessary, an emergency airdriven generator can be dropped in the airstream below the fuselage to provide power for the hydraulic systems.

9. A valve is a device that controls the movement (speed, direction, and/or volume) of a fluid within a system.

   A pump is a device that applies a force to move fluid within a system.

10. The urinary system is not a pneumatic system because the system holds a liquid. The urinary system is a hydraulic system only while the sphincter that controls urination is closed. Otherwise, the system is open. Hydraulic systems must be closed.

11. Pressure applied by the heart and skeletal muscles along the outside of the vein provides the necessary pressure to move the blood. One-way valves respond by opening under pressure. Their tiny pockets are filled (closing the valve) when the muscle relaxes, keeping the blood from flowing back under the force of gravity.

12. **Textbook questions 1, 3, and 6 from "Topic 5 Review," page 325:**

    1. Gases compress under pressure and liquids do not. Both types of fluids transmit pressure equally in all directions.

    3. In pneumatic systems the gas must be kept compressed to transmit a force fully and instantaneously. Uncompressed gas is used to absorb energy. The particles of a liquid are already close together. They readily transmit force.

    6. Answers will vary. A good model for a lift based on an inflatable air bag is a balloon under a book. A straw should be attached to the balloon and used to inflate the balloon. This will lift the book.

Section 2: Lesson 3

1. These brakes are a hydraulic system. **Note:** Large trucks often have "air brakes." Such brakes are pneumatic systems.

2. **a.** The pedal to piston subsystem is a Class 1 lever. The disc is a wheel and axle.

   b. The brake system is a subsystem of the car. A car is a very complex system made up of many interdependent subsystems. The brake system is a subsystem in the sense that it contributes to the operation of a larger system—the vehicle itself.

Section 3: Lesson 1

1. Answers will vary. The invention of the steam engine created the ability to move more things faster over greater distances. It began the move to develop similar transportation technologies (cars, ocean liners, planes). Large steam-powered engines brought about the Industrial Revolution and urbanization as people left their rural homes to work in urban factories.

2. Answers will vary. All known modes of transport in the nineteenth century moved at slow speeds. Steam engines moved at a dangerous new speed. To many people, the steam locomotive was an "experimental" technology, which made it untrustworthy. It was also noisy, dirty, and disruptive.

3. **Textbook questions 1 to 3 from "What Did You Find Out?" on page 333:**

    1. Today's transportation technology and infrastructure (roads, railroads, airports, and so on) allows for much faster and easier travel than in the past, when people did not regularly travel great distances to work or for recreation.

    2. If you walk to school, the distance is likely shorter than it was for your parents and grandparents. Many students today ride in buses or cars to get to school.

    3. You might attend an on-line school from your home computer.

4. An exhaust valve is a movable part that releases spent (used or waste) gases.

5. Hot, less dense air is buoyed up by cold, denser air. **Note:** For hot air to rise, there must be cooler air nearby.

6. The pathway may be summarized as follows: chemical energy of the fuel → thermal energy → kinetic energy of steam → mechanical energy of the piston → mechanical energy of the wheel.

7. Stationary blades direct the angle at which steam hits the turbine.

8. The first practical internal combustion engine was produced in 1876 in Germany.

9. A complete cycle consists of the following strokes: intake, compression, power, and exhaust.

10. The piston rods are connected to a crankshaft that converts the back-and-forth motion of the piston into rotary motion.

11. **Textbook questions 1 to 3 from "What Did You Find Out?" on page 340:**

    1. The air pressure is greatest under the sheet; that is why the sheet lifted up.

    2. Blowing against the page corresponds to how kites fly. Kites remain aloft due to pressure caused by air pushing (in the form of wind) against their lower surface.

    3. Blowing over the sheet of paper corresponds to how aircraft wings work. Air moving faster over the top surface reduces the pressure on the top to create lift. **Note:** The reduced pressure due to moving air above the wing is explained by Bernoulli's principle—you may recall this principle from the science you learned in elementary school.

Section 3: Lesson 2

4. A more effective process of manufacturing iron by using coal for fuel was developed. This process made it easier to make the iron to manufacture machines to be driven by steam engines.

5. Mass production is the manufacturing of large quantities of an item by a certain mechanical process (for example, appliances, automobiles, food processing, computers, and furniture).

6. During the Industrial Revolution, people began to move from rural areas (farms and small towns) into urban areas (cities). People working out of their homes in rural areas (cottage industries) could not compete with the mechanized operations in urban areas.

7. Obvious differences are the smaller size and the aerodynamic shape of late-model cars, compared to the earlier designs. Cars are also lighter, more fuel efficient, and have pollution-reduction devices. Although it's not obvious from the photos, newer cars also have safety features such as seatbelts and airbags.

8. The following are some environmental changes related to the development of the automobile:

- massive road systems
- hectares of parking lots (that affect water distribution and quality and carve up habitats)
- tonnes of pollutants (for example, carbon monoxide, nitrogen, sulphur oxides, hydrocarbons, and particulates)
- massive support industries with associated environmental costs (for example, the petrochemical, steel, and paint industries) and associated waste disposal (for example, tires, lubricants, and car bodies)

The following are some societal changes:

- Greater mobility has allowed the development of extensive travel and entertainment industries. People can now frequently and easily travel from the home to watch movies, dine in restaurants, attend concerts, vacation in the mountains, and so on.
- Cities sprawled out as commuting to work became easier.
- Increased and improved transportation allowed a global market for consumer goods (import of foods, technology, raw materials, and manufactured goods).

9. Solar panels, fuel cells using hydrogen as a fuel, and storage batteries are being tried out in cars.

11. Sleeping on an air mattress is more comfortable than sleeping on a hard surface because the mattress shapes itself to body contours. This means a person's weight is spread over a large surface, so pressure points are avoided.

12. Changes include

- wheelchair ramps and lifts
- wheelchair-accessible washrooms
- automatic doors
- hand-operated cars and bicycles
- ergonomic seats
- motorized wheelchairs
- improved wheelchair support systems (stronger, light-weight materials)
- specialized wheelchairs adapted for specific needs

Mechanical Device Rules

***Rule 1.** A comparison of the **effort force** (F_E) and the **load force** (F_L) indicates which of the following is more—the distance the effort moves (d_E) or the distance the load moves (d_L). The comparison of these forces also indicates the mechanical advantage (*MA*) and the speed advantage (*SA*).

If $\boldsymbol{F_E}$ is **less** than $\boldsymbol{F_L}$, then

- $\boldsymbol{d_E}$ is greater, i.e., the effort force goes through a greater distance
- ***MA*** is greater than **1**

That makes SA less than 1; the device makes the work slower but "easier" in terms of the force you need to apply.

If $\boldsymbol{F_E}$ is **greater** than $\boldsymbol{F_L}$, then

- $\boldsymbol{d_L}$ is greater, i.e., the load goes through a greater distance
- ***MA*** is less than **1**

That makes SA greater than 1; the device makes the work faster but "harder" in terms of the force you need to apply.

If $\boldsymbol{F_E}$ is **equal** to $\boldsymbol{F_L}$, then

- $\boldsymbol{d_L}$ and $\boldsymbol{d_E}$ are equal, i.e., the load and effort force go through an equal distance
- ***MA*** is equal to **1**

Here SA is equal to 1; the device makes the work no faster and "no harder" in terms of the force you need to apply. The load and effort are likely in opposite directions to make the work easier to perform.

Rule 2. The **greater the distance ratio** of d_E to d_L, the **greater the mechanical advantage**, i.e., the greater the force advantage.

Rule 3. Mechanical **work** is done only when an object is moved through a **distance (*d*)** by a **force (*F*)**. (See page 276 of the textbook.)

$W = Fd$

The amount of work done is the product of force (F) and distance (d) through which the force is applied. The work done in operating a machine is the product of effort force (F_E) and the distance the effort force moves (d_E). (See page 298 of the textbook.) The work done by the machine on the load is the product of the load force (F_L) and the distance the load moves (d_L).

Rule 4. A simple machine **cannot reduce the amount of work** required to do a particular job. But a machine can make the work easier by

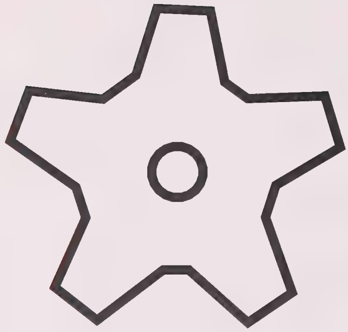
- lowering the effort force needed or by providing a speed advantage
- changing the direction in which force needs to be applied

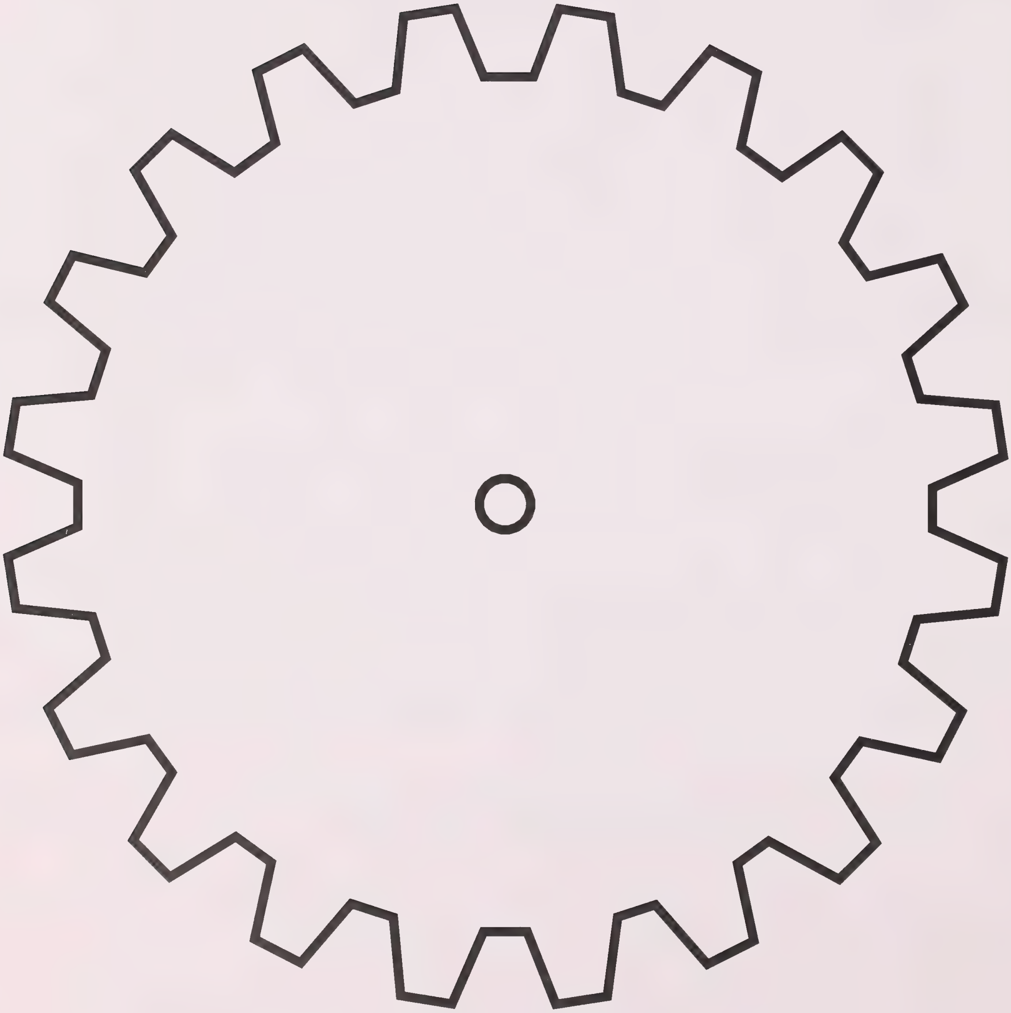
Notes:

* To simplify things, a machine may be considered to be "perfect"—working without friction. Rule 1 is true for perfect machines. In such perfect machines, the input work exactly equals the output work.

With a "real" machine you always end up doing more work. That's because you must overcome the friction of moving parts of the machine. That makes the input work you do a bit more than the output work of the machine.

Gear Templates





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